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Improving the attractiveness of CDM projects through allowing and incorporating options

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HIGHLIGHTS

- The paper proposes that options be allowed within CDM projects.
- Introducing options will require a CDM rule change.
- Options improve the financial attractiveness of CDM projects.
- Allowing options comes at no cost or detriment to any party.
- Allowing options is a win–win situation to both society and the project proponent.

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ABSTRACT

The paper puts forward a proposal that, within Clean Development Mechanism (CDM) projects, investors be allowed to benefit from options; this will require a CDM rule change. Through the presence of options, the downside risk resulting from low carbon prices and/or low achieved emission reductions on projects can be limited, while any upside resulting from high carbon prices and/or high achieved emission reductions can be taken advantage of. It is demonstrated that the presence of options improves the financial attractiveness of CDM projects, and this is at no detriment to any stakeholder. The flow-on from the proposal is that more CDM projects should be realisable if options are available, and this in turn will lead to reduced global emissions and improved sustainability. The proposal is supported by the necessary theory and is demonstrated on two registered CDM projects, one on hydropower and one on wind power.

1. Introduction

The Clean Development Mechanism (CDM) is one of three flexible emission reduction mechanisms flowing from the 1997 Kyoto Protocol (UNFCCC, 2015c), where certified emission reduction credits or units (commonly referred to as CERs or carbon credits) are generated in developing countries for use by industrialised countries (referred to as Annex 1 parties - UNFCCC, 2015c) in achieving their emission reduction targets. Although the Protocol expired on 31 December 2012, the 18th session of the Conference of the Parties (COP 18) in Qatar (UNFCCC, 2015g) extended the duration of commitments to 31 December 2020. The aim of CDM projects is to encourage sustainable development and to reduce global emissions at least cost (UNEP, 2003; UNFCCC, 2015c, 2015f). CERs are generated by the projects for every tonne reduction in carbon dioxide equivalent (CO2-e) below a defined baseline; this ensures the environmental worth of a CDM project (Schneider 2007; UNEP, 2007). CERs can be traded and sold in carbon markets, or used by organisations to comply with emission targets (UNEP, 2003, 2007).

In order to access CERs, a project requires upfront registration, validation and ongoing compliance checking, all of which have transaction costs, additional to regular project costs, detracting from investing in CDM projects. These transaction costs affect project viability (Michaelowa et al., 2003; Michaelowa and Jotzo, 2005). The paper proposes one way whereby the influence of these transaction costs can be reduced.

The value of CERs fluctuates with the price of carbon in the carbon markets, and CER output generated by a project may fluctuate, and so the project income from CERs contains uncertainty. This, in turn, affects the project's attractiveness. Potential downward price fluctuations might be mitigated with futures

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contracts in which a CER price at a given date is locked in, however this loses any favourable market price movements. Options can also be held on carbon prices, but not on project CER output. It would appear reasonable therefore to build in the potential for options in CDM projects, whereby the project can benefit from CERs when the CER price and/or project CER output are favourable (upside), but not be put to the expense of ongoing compliance costs when the CER price and/or project CER output are unfavourable (downside). This decreases the financial risk of a CDM project, and makes CDM projects more attractive financially.

An option, in general terms, is a right but not an obligation to do something. In this paper, the option refers to the choice of whether to claim carbon credits or not depending on the changing carbon price and/or project CER output. Allowing options gives the investor freedom to walk away from, or take advantage of, the carbon-based revenue side of the project at any given time. Options allow the investor to make choices throughout the project lifespan, and having these choices or flexibility leads to a higher investment value. Options turn the exposure associated with the uncertainty in future carbon prices and/or project CER output to the investor's advantage.

Introducing options will require a CDM rule change. (For an explanation of current rules, refer Baker and McKenzie, 2015.) Allowing options, in turn, should lead to higher CDM viability and more CDM projects, leading to more global emission reductions.

The paper's argument is developed firstly through giving the proposal in Section 2. Some background information on CDM projects and carbon markets follows. The presence of uncertainty in the CER price and project CER output, together with the introduction of options, implies a probabilistic analysis. This paper does this through a straightforward second order moment analysis using expected values and variances only of project cash flows (Carmichael, 2014), but any other equivalent method, such as Monte Carlo simulation, could be used. Two registered CDM projects are used to support the paper's proposal, one on hydropower and one on wind power.

The paper will be of interest to investors, project developers and policy makers involved with CDM projects, and generally to those concerned about greenhouse gas emission reductions and sustainability. The paper's idea of allowing options within CDM project rules is original. Policy issues relate to the UNFCCC rules overseeing CDM projects (UNFCCC, 2015c,d).

Only financial matters relating to CER price and project CER output are addressed in this paper. Technological, political, environmental and administrative and procedural matters, as well as project performance are not discussed.

2. Methods

2.1. Inclusion of options

Given the carbon-emission reduction and sustainability benefits of CDM projects, it would appear reasonable that CDM projects should be encouraged. One way to do this is to make CDM projects more financially attractive.

The paper is proposing that the full extent of options be allowed with CDM projects in order to increase the attractiveness and number of CDM projects. This will involve a CDM rule change. Discussion is given below on any detriment that may flow to any stakeholder from such a rule change.

An option is a right, but not an obligation to do something. The right is usually established through the paying of a premium, and the option is only exercised if it is favourable to do so. For example, within the financial derivatives literature, an option right involves buying or selling an underlying asset at a specified price on or before a specified date. In the context of this paper's proposal, namely options in conjunction with CDM projects:

1. The right is to claiming carbon credits (CERs) during the CER crediting period – credits may or may not be (optionally) claimed, depending on the current CER price and/or project CER output.
2. The credits obtained represent a positive cash flow; the cost of making a claim for the credits represents a negative cash flow.
3. The premium paid, at project outset, is the cost of establishing the project as a CDM project.
4. The time of exercising the option is during the CER crediting period; typically each year during this period, a decision is made to exercise the option or not.

Carbon credits will only be claimed (that is, the option will only be exercised) if it is favourable to do so. In years where the price of carbon is high (low) and/or the project CER output is high (low), whereby the return from CERs is greater (less) than the cost of their claiming, the option is (not) exercised.

This flexibility in decision making has a value, and (based on established decision logic) it is always greater than the value of having to always claim credits every year during the crediting period (namely the current CDM practice). That is, allowing options increases the attractiveness of CDM projects.

The CDM project-style options belong to what is called real options. The preferred method of analysis used here is that based on cash flows (Carmichael et al., 2011); methods based on financial options analogies require assumed characteristics of underlyings and for that reason are not used here. This analysis is explained below.

2.2. Background - Clean Development Mechanism

2.2.1. General

The Clean Development Mechanism, under the Kyoto Protocol of 1997, is an attempt to reduce global carbon emissions at low cost, and promote sustainable development. Developed countries can invest in projects located in developing countries, and receive CERs. However, because of the volatility in the price of carbon, amongst other things, CDM projects have not reached their full potential, and investors are naturally cautious.

Proposed CDM projects and the issuance of CERs are subject to approval by an Executive Board (EB), in order to ensure that emission reductions are real and additional (Baker and McKenzie, 2015). Emission reductions are relative to a baseline, which follows from using approved baseline methodologies (UNFCCC, 2015c). Emissions are checked to see that they are below that which would have occurred in the absence of the CDM project (the business-as-usual case), while financial additionality requires demonstrating that the project is not viable without CDM classification (and hence CER revenue) (Chadwick, 2006; Chen and Wu, 2011; Carmichael et al., 2015). Typically, financial additionality using internal rate of return is checked deterministically, ignoring any uncertainty in carbon price and project CER output.

The progress of the Clean Development Mechanism has been impressive in terms of registered projects, and CERs supplied (UNFCCC, 2015d), though the current low price for carbon is restrictive. Along the way there have been teething issues, and suggestions for streamlining approvals and baseline methodologies have been made in order to reduce transaction costs and speed up project registration (for example, Michaelowa, 2005; Schneider, 2007; Lecocq and Ambrosi, 2007; Michaelowa and Purohit, 2007; Gillenwater and Seres, 2011). Projects are subject to rigid crediting periods and practices, and are unable to respond to fluctuating carbon prices and/or project CER outputs (Michaelowa, 2005; Teng and Zhang, 2010; Pechak et al., 2011).

2.2.2. Options and CDM projects

Options in conjunction with CDM projects have been suggested in other publications. However their usage is in a different sense to that in this paper. Tucker (2001) suggested purchasing and selling options in carbon tradable offsets until true market offset trading developed. Lee et al. (2013) use options to develop a negotiation stance, based on risk sharing, between the host country and the investor, where CDM projects are viewed as emissions trading between developed and developing countries. Uhrig-Homburg and Wagner (2008) discuss the derivatives market in emissions trading. As well, there are futures contracts (for example, Uhrig-Homburg and Wagner, 2007; Carmona and Hinz, 2011), insurance policies and hedging practices that allow an investor to reduce risk associated with carbon prices. There is nothing published that deals with both fluctuating CER prices and fluctuating project CER output, options and rule changes in CDM projects.

2.2.3. Costs

Costs and revenue in the following refer only to carbon-based costs and revenue, and not to total project costs and revenue. Only carbon-based costs and revenue are relevant in the option calculations.

Transaction costs are (1) upfront or pre-operational, and (2) ongoing or operational (UNEP, 2003, 2007, 2011; Krey, 2005; Chadwick, 2006):

1. Upfront or pre-operational costs include search costs, negotiation costs, validation costs and approval costs, made up of CDM project cycle costs for preparation and review, baseline study, environmental assessment, stakeholder consultation, approval, validation, consultation and project appraisal, and legal and contractual arrangements. Upfront approval and registration requires the preparation, by the project proponent, of a Project Design Document (PDD), which describes the project and includes information on baseline methodology, emission reduction calculations, duration and crediting period of the project, additionality and sustainability criteria, and environmental impact. The project is put forward to the host country for approval, and to ascertain that the project contributes to the country's sustainable development goals (UNEP, 2007). A Designated Operational Entity (DOE) reviews the PDD. Having been validated, the project can then be registered (up to the time of the project being operational) with the EB for a fee dependent on the annual amount of CO2-e that is given as being reduced. The fee is paid upfront, but is later deducted from the share of proceeds at the issuance of the CERs.
2. Ongoing or operational costs include monitoring costs, certification costs and enforcement costs made up of CDM project cycle costs for sales of CERs, adaptation levy, risk mitigation, verification and EB administration. A monitoring report gives estimates of the CERs generated and is submitted for verification to a DOE, which checks against an approved methodology, and subsequently for approval by the EB. Certification by the DOE, that the project has achieved the emission reductions, leads to the issuance of a verified amount of CERs. The frequency of issuance varies among projects, however once a year is common. There is also an adaptation fee (exempt for least developed countries), calculated at 2% of the CERs claimed; this goes to a fund to help developing countries' adaptation to a changing climate.

Of particular relevance to this paper are the monitoring, verification and certification costs. In monitoring, GHG emissions and associated information (fuel consumption, emission factors, heat and electricity production, and grid losses) are measured and analysed. During verification, the authenticity of the calculated emission reductions is assessed. This is done by a different DOE to that which performed the validation. The DOE ensures that the CERs are in accordance with the guidelines and conditions agreed upon in the initial validation. Certification is a written assurance by the DOE that, during the nominated time period, the project has achieved the emission reductions calculated. Project participants are notified of the certification outcome, and this includes a request to the EB to issue CERs equal to the verified amount. The EB issues CERs within 15 days of this request.

The ongoing costs apply over a crediting period. The crediting period is the time period chosen, prior to registration and stated in the PDD, by the project proponents over which CERs are claimed. A project can have either: a single 10-year crediting period; or a 7-year crediting period that can be renewed twice (subject to approval by the EB), giving a maximum of 21 years (Baker and McKenzie, 2015). The process for renewal approval includes: an updated PDD using the latest approved baseline methodology, and validated by the DOE; a new letter of approval; and a request for renewal.

The crediting period begins once the project enters its operation phase, however its start can be delayed or brought forward by up to a couple of years (UNFCCC, 2015e-EB 52 Report, Annex 59). This change in the start date can only be made once for each project.

UNEP (2003, 2007, 2011) and others give typical transaction costs for small-scale (<15 MW) and large-scale (>15 MW) projects. Transaction costs vary according to the scale of the project. UNEP (2003, p. 65) comments that ‘project developers generally expect upfront transaction costs within the range of 5–7% of the net present value of the revenue or total transaction costs around 10–12% of the net present value of revenue’. Many of the transaction costs are fixed and therefore smaller-scale projects may have higher transaction costs per tonne of CO2-e, making them less attractive to investors (Michaelowa et al., 2003).

The registration fee paid is dependent on the amount of CERs generated, and is calculated according to a scale; the more CERs generated, the higher the rate per CER. The registration fee is capped, and least-developed countries are exempt from paying this fee (Baker and McKenzie, 2015).

2.2.4. Revenue

Revenue in the following refers only to carbon-based revenue, and not to total project revenue (which would include the sale of the project end-product). Only carbon-based revenue is relevant in the option calculations.

CERs are generally claimed on an annual basis within the crediting period, once verification and certification have been achieved. The CERs generated by the project may be sold. Their financial value equals the project CER output multiplied by the CER market price.

The market value of CERs during the (future) crediting period is crucial to establishing whether a project is worthwhile registering as a CDM project. Future carbon prices might be estimated based on historical performance as well as consideration of events that might impact the future price. UNEP (2003, p. 61) comments that ‘the pricing of CER is highly speculative’. Consideration needs to be given to both the compulsory and voluntary carbon credit supply and demand, the various country emissions trading schemes, carbon legislation, economies and government policies around the world (Feng et al., 2011; Morgan, 2009). Currently, there is an oversupply of carbon credits and the price of carbon is at an all-time low due to a disparity between demand and supply. The current CER market conditions are not as prosperous as they used to be with the market size decreasing.

Viability as a CDM project, in contrast to other project types, requires that the CDM-specific costs be less than the CER revenue generated.

2.3. The relevant options analysis

2.3.1. Outline

The options analysis is based on the cash flows resulting from and including exercising the option (that is, claiming the carbon credits). At time $i = T_S, T_S+1, \ldots, T_F$, let the revenue generated by the CERs claimed be Y_{i1}, and let the cost of claiming the carbon credits be Y_{i2}, where T_S and T_F are the start and finish times (years) of the crediting period. The below analysis allows for both Y_{i1} and Y_{i2} to be random variables, though in many cases only Y_{i1} will be a random variable.

Let the difference in revenue and costs at any time i be $X_i = Y_{i1} - Y_{i2}$. Then,

$$E[X_i] = E[Y_{i1}] - E[Y_{i2}]$$

$$Var[X_i] = Var[Y_{i1}] + Var[Y_{i2}] - 2Cov[Y_{i1}, Y_{i2}]$$

where $E[\ ]$ and $Var[\ ]$ denote expected value and variance respectively. Present worth, PW, of the difference in revenue and costs at any time i becomes,

$$PW = \frac{X_i}{(1+r)^i}$$

where r is the interest rate. The relevant interest rate contains no loading for any uncertainty, because the uncertainty in the cash flows is already accounted for in their variance terms.

It follows that,

$$E[PW] = \frac{E[X_i]}{(1+r)^i} \tag{1a}$$

$$Var[PW] = \frac{Var[X_i]}{(1+r)^{2i}} \tag{1b}$$

(Eqs. (1a) and (1b) can be enlarged if the costs and revenues occur over more than one time period.)

Fitting a probability distribution to PW, then the value of having the option to claim is (Carmichael et al., 2011),

$$OV = \Phi \times Mean\ of\ PW\ upside \tag{2}$$

where $\Phi = P[PW > 0]$ and is termed 'feasibility', $P[\ ]$ is probability, '*PW* upside' is the positive part of the present worth probability distribution, the mean of this upside is measured from the origin, and OV is the option value. In the evaluation of OV, a probability distribution for PW is assumed. Commonly a normal distribution is assumed (Hillier, 1963; Tung, 1992), but any suitable distribution can be used. The shape of the distribution for PW follows from knowing $E[PW]$ and $Var[PW]$ from Eqs. (1a) and (1b). Fig. 1 shows an example PW upside involved in calculating the option value.

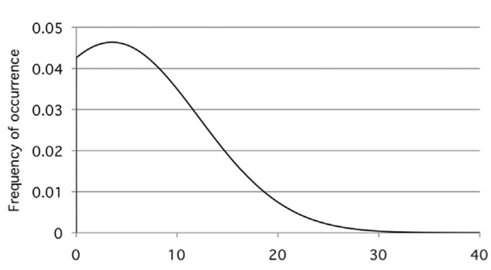

Fig. 1. Example upside of *PW* distribution; Φ is the area under the curve; '*Mean of PW upside*' is the mean of the area under the curve measured from the origin.

2.3.2. Summary calculation steps

The following is a summary of the steps involved in calculating the option value.

1. Obtain estimates for $E[Y_{i1}]$, $E[Y_{i2}]$, $Var[Y_{i1}]$, and $Var[Y_{i2}]$. This may be done in many ways, but in the absence of anything else, a useful way is for example through first estimating optimistic (a), most likely (b) and pessimistic (c) values, as in the Program Evaluation and Review Technique (PERT) (Malcolm et al., 1959; Carmichael, 2006), from which the expected value or mean $= (a+4b+c)/6$, and variance $= [(c-a)/6]^2$ can be calculated. Correlations between the cost components are also needed, and these might best be estimated based on knowledge of the particular components and their paired relationships, rather than through any involved mathematical analysis. Such estimates would be done to a level of accuracy comparable to other estimates in the PDD, and would be based on the same sources.
2. Calculate $E[PW]$ and $Var[PW]$ using Eqs. (1a) and (1b).
3. Fit a probability distribution to PW, and calculate Φ and '*Mean of PW upside*'. Commonly, a normal distribution might be assumed for PW.
4. Calculate the option value, OV, from Eq. (2).

2.3.3. Case examples

The calculations are demonstrated on two CDM projects, available at UNFCCC (2015a,b) - one on hydropower, the other on wind power. All relevant information regarding costs and crediting periods are from the respective published PDDs. Interest rates used are those applicable to the country during the relevant crediting periods. To this, optimistic, most likely and pessimistic CER price estimates are made using the best available information, and the above-given PERT approach is used to calculate expected values and variances. The project PDDs use crediting periods of 10 years.

3. Results

3.1. Case example – hydropower

3.1.1. Description

The case example covers a hydropower project in India (UNFCCC, 2015a), supplemented with additional material necessary for option calculations. The project is canal-based, utilising the flows and head available from a diversion channel. It is classified as a small-scale project due to its total installed capacity of 2 MW. The project generates electricity through sustainable means and is not anticipated to cause any harm to the environment, while contributing to emissions abatement.

The project has a fixed crediting period of 10 years (2012–2022). The project is anticipated to have zero project and leakage emissions, thus emission reductions are equal to the baseline emissions. PDD baseline calculations show that the hydro plant generates 10,356 MWh per annum with an emissions factor of 0.9032 t CO2-e/MWh, giving baseline emissions as 9357 t CO2-e per annum.

3.1.2. Upfront/pre-operational costs

The upfront costs are estimated as $80k (based on the project's PDD, or estimated – UNEP, 2003, 2007, 2011; Tanwar, 2007), being comprised of:

1. Search costs and Project Design Document (PDD) - $40k.
2. Baseline methodology and estimate of emissions in absence of

the project - \$15k.
3. Approval (by designated national authority) costs - \$12.5k.
4. Validation costs (project eligibility regarding CDM requirements) - \$12.5k.
5. Registration - \$0.

3.1.3. Annual ongoing/operational costs

The ongoing annual costs are estimated as \$15k–\$20k (UNEP, 2003, 2007, 2011; Tanwar, 2007), being comprised of:

1. Monitoring costs, including reporting - \$5k.
2. Verification costs - \$5k. (with an extra \$5k, once only, at the start of the crediting period.)
3. Certification (assurance by DOE of the emission reductions) - \$5k.
4. Adaptation fee (used to fund climate change adaptation assistance) - 2% of CERs generated.

This gives for annual total cost, Y_{i2},

$E[Y_{i2}]=\$15k$ (with \$20k in year 1 - 2012 - of the crediting period)

These costs are assumed here to be relatively certain over time, that is $Var[Y_{i2}]=0$.

Item 4 is taken care of in the following calculations by only using 98% of the CERS generated as income, rather than 100%.

3.1.4. Annual revenue

In establishing CER price estimates, historical data and carbon market reports are available commercially (Intercontinental Exchange, Thomson Reuters and elsewhere). For example purposes, pessimistic, most likely and optimistic estimates are taken as \$1.00/t, \$2.50/t and \$8.00/t respectively, and apply throughout the whole crediting period. This gives an expected value and variance of the price of \$3.17, and $(\$1.17)^2$ respectively.

The PDD gives estimated annual project CER output (emission reductions) as 9357 t. Based on Balatbat et al. (2012) and Cormier and Bellassen (2013), and for example purposes, pessimistic, most likely and optimistic estimates are assumed to be 5000 t, 7500 t and 10,000 t respectively. This gives an expected value and variance of the CER yearly output of 7500 t, and $(833\text{ t})^2$ respectively.

Other values for CER prices and output, including different values for each year, might be assumed by different investors. For example, the variance in the CER price might be assumed to increase with time in order to reflect future uncertainty in a better way. However the form of the calculations, exampled here, does not change.

For independence of CER price and output, this gives for annual revenue, Y_{i1},

$E[Y_{i1}] = 3.17 \times 7500 = \$23.8k$

$Var[Y_{i1}] = 3.17^2 \times 833^2 + 7500^2 \times 1.17^2 + 1.17^2 \times 833^2 = (\$9.2k)^2$

3.1.5. Present worth and option value

With expected values and variances in hand for the ongoing annual costs and annual revenue, these may be discounted to the start of the project using Eqs. (1a) and (1b). The discount rate given in the PDD is 9.41% per annum. Assuming that this incorporates some allowance for uncertainty, a 7% per annum interest rate is used here for example purposes. Other rates might be assumed by different investors; however the form of the calculations, exampled here, does not change. Eq. (2) is used to calculate the option value. Table 1 gives the calculations for the end of each year of the crediting period, relative to the start of the crediting period.

The additional value (here 11.06% over all years), obtained by allowing options in each year, is demonstrated in Fig. 2. The added value comes from capping any downside resulting from low carbon prices and/or low project CER output, but taking advantage of any upside resulting from high carbon prices and/or high project CER output. Comparing \$57.13k or \$63.45k with the upfront cost of \$80k, the project is not viable from a CDM viewpoint; however allowing options decreases the loss to the investor.

Table 1
Hydropower case example; yearly option values compared with deterministic present worth (*E[PW]*); *StDev* is standard deviation.

Crediting period (year)	$E[PW]$ (\$k)	$StDev[PW](\sqrt{Var[PW]})$ (\$k)	Option value (\$k)
1	3.55	8.60	5.45
2	7.69	8.04	8.31
3	7.18	7.51	7.76
4	6.71	7.02	7.25
5	6.27	6.56	6.82
6	5.86	6.13	6.35
7	5.48	5.73	5.92
8	5.12	5.35	5.57
9	4.79	5.00	5.19
10	4.47	4.68	4.82
Sum	57.13		63.45
% increase			11.06

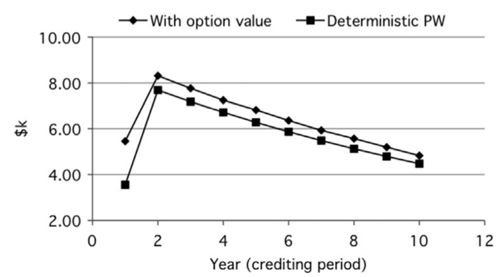

Fig. 2. Hydropower case example; additional value, obtained by allowing yearly options, is the difference between the two plots.

3.2. Case example – wind power

3.2.1. Description

The second case example used to demonstrate the value of allowing options is based on a bundled wind power project (UNFCCC, 2015b), based in India. It involves the installation of 5 wind turbine generators, of total capacity 7.5 MW and anticipated to generate 17,838 MWh per annum. As a bundled project, the project only needs a single validation report and a single certification report.

Generated power is sold to a local electricity authority. The project contributes to emission reductions through replacing the burning of fossil fuels. The generators are assumed to not use any fuel and therefore the project emissions are taken as zero.

The PDD uses a 10-year crediting period, from 2012 to 2022.

3.2.2. Upfront/pre-operational costs

The upfront costs are estimated to total \$73.94k (based on the project's PDD, or estimated using UNEP, 2003, 2007, 2011), being made up as follows:

1. Search costs and Project Design Document (PDD) - \$13.5k
2. Baseline methodology - \$10k
3. Approval - \$5k
4. Validation costs and services - \$42k
5. Registration - \$1.69k
6. Monitoring plan - \$1.75k

3.2.3. Annual ongoing/operational costs

The ongoing annual costs are estimated as $20k (Painuly et al., 2005; UNEP, 2003, 2007, 2011), being comprised as follows:

1. Monitoring - $10k
2. Verification - $5k
3. Certification - $5k

As well, there is a UN adaptation fee calculated at 2% of CER revenue.

This gives for annual total cost, Y_{i2},

$E[Y_{i2}] = \$20k$

These costs are assumed to be relatively certain over time, that is $Var[Y_{i2}]=0$.

3.2.4. Annual revenue

The PDD gives annual CER output (emission reductions) of 16,001 t CO2-e for years 1–8, dropping to 15,841 and 15,683 t CO2-e for years 9 and 10 respectively. Using the reasoning of the previous hydropower case, and for example purposes, yearly pessimistic, most likely and optimistic estimates are assumed to be 8000 t, 12,000 t and 16,000 t respectively. This gives an expected value and variance of yearly CER output of 12,000 t, and $(1333\ t)^2$ respectively.

CER price estimates, for example purposes, are taken as the same as the hydropower case study.

Other values for CER prices and CER output, including different values for each year, might be assumed by different investors. However the form of the calculations, exampled here, does not change.

For independence of CER price and output, this gives for annual revenue, Y_{i1},

$$E[Y_{i1}] = 3.17 \times 12000 = \$38.0k$$

$$Var[Y_{i1}] = 3.17^2 \times 1333^2 + 12000^2 \times 1.17^2 + 1.17^2 \times 1333^2 = (\$14.7k)^2$$

3.2.5. Present worth and option value

The PDD uses a discount rate of 8.1706% per annum. Assuming that this includes some allowance for uncertainty, the following calculations use a lower value of 7% per annum, for example purposes. Other rates might be assumed by different investors; however the form of the calculations, exampled here, does not change.

Eqs. (1a), (1b) and (2) are used to calculate present worth and option values. Table 2 gives the calculations for the end of each year of the crediting period, relative to the start of the crediting period.

Table 2
Wind power case example; yearly option values compared with deterministic present worth ($E[PW]$).

Crediting period (year)	$E[PW]$ (\$k)	$StDev[PW](\sqrt{Var[PW]})$ (\$k)	Option value (\$k)
1	16.82	13.74	17.20
2	15.72	12.84	16.13
3	14.69	12.00	15.02
4	13.73	11.21	14.08
5	12.83	10.48	13.19
6	11.99	9.80	12.34
7	11.21	9.15	11.46
8	10.48	8.56	10.72
9	9.79	8.00	10.10
10	9.15	7.47	9.44
Sum	126.42		129.68
% increase			2.58

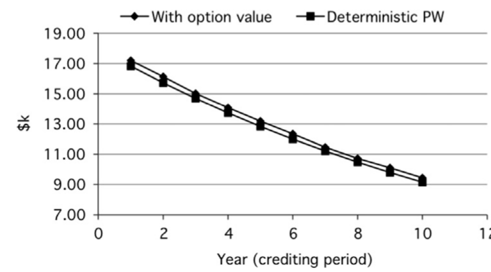

Fig. 3. Wind power case example; additional value, obtained by allowing yearly options, is the difference between the two plots.

The additional value (here 2.58% over all years), obtained by allowing options in each year, is demonstrated in Fig. 3. The added value comes from capping any downside resulting from low carbon prices and/or low project CER output, but taking advantage of any upside resulting from high carbon prices and/or high output. Comparing $126.42k or $129.68k with the upfront cost of $73.94k, the project is viable from a CDM viewpoint; however allowing options increases the viability, albeit here only slightly, to the investor.

4. Discussion

4.1. General comments

In amplification of the above analysis and case example calculations, the following comments are given:

I. Whether it is worthwhile to seek CDM registration for a project requires a comparison of the upfront/pre-operational costs and on-going/operational costs with the revenues gained. Additional to this, allowing options improves the viability. Options may convert an unviable project into one that is viable, while they increase the viability of an already viable project. It is seen in the case examples presented, that even when the overall project deterministic present worth is negative, options still have a value, albeit small in some cases. Incorporating options always leads to a value greater than the equivalent deterministic present worth of any investment. This added value comes from having the right but not the obligation to claim or not claim carbon credits at any time. Numerically, this was demonstrated in the case examples. Only when the feasibility, Φ, has a value of 1 does the option value not add anything to the project viability. However, in this case the investment is already sufficiently attractive without any consideration of options.

II. The calculations rely on forecasting future CER prices, project CER output and CDM-based costs, and their variability. Any means may be used to do this, for example, for CER prices, using a combination of time series models, experience, and knowledge of factors (supply/demand, …) affecting prices. Forecast estimates inherently contain uncertainty. CDM projects have uncertainty in future CER price, project CER output and CDM-based costs. It is this uncertainty which gives an option its value. The greater the uncertainty (as measured by variances), the greater the option value. In the case examples, the costs were assumed fixed; however, the option value will increase if costs also contain uncertainty (based on costs and revenue being largely independent).

III. The general conclusions of the paper are not sensitive to changes in underlying assumptions in crediting period, interest rate, and uncertainty and magnitude of CER price, project CER output, and compliance cost. The magnitudes of the calculated option values change, but not the overall conclusion that allowing options increases the attractiveness of CDM projects.

IV. The transaction costs per CER for large-scale projects are smaller than for small-scale projects where the transaction costs can be quite significant. Hence it is anticipated that having recourse to options will benefit small-scale projects more than large-scale projects. Any simplification of procedures and standardisation of reporting would reduce transaction costs and increase the option values.

V. The case example analyses were based on the possibility of exercising options on a yearly basis. The analysis changes little should options be allowed to apply to several consecutive years treated as one; revenues for each year are summed and discounted, while on-going costs may increase but be fewer in number, and would also be discounted. It is seen that allowing options in any form increases the attractiveness of a CDM project.

VI. The inclusion of options does not affect CDM financial additionality, which essentially only requires that the project not be viable without CER revenue. The inclusion of options only affects viability from the project investor's viewpoint.

VII. It is seen that allowing options comes at no detriment to any stakeholder. It is a win–win situation – global emissions are reduced further by making more CDM projects viable, while project proponents potentially could gain financially, or lose less. Opportunity costs are no different to, or are less than the current CDM situation, where options are not permitted.

4.2. Policy

The paper suggests that CDM rules should be modified in order to improve the attractiveness of CDM projects. The increased attractiveness, in turn, should lead to more CDM projects, contributing to greater global emission reductions. The modification suggested is that options be allowed.

Currently CDM rules allow for minor accelerating or delaying the claim for CERs at the start of the crediting period. Paragraphs 3, 7, 8 and 10 of UNFCCC (2015e, p. 1) give:

3. This document contains procedures for requesting changes in the start date subsequent to the registration of a CDM project activity.

7. Participants of projects for which the start date of the crediting period is after the date of registration may:

(a) *Inform the secretariat that the start date of the crediting period be moved to a date up to one-year earlier than the one indicated in the PDD, …*
(b) *Inform the secretariat to delay the start date of the crediting period by up to one-year;*
(c) *Make a request to the secretariat, via a DOE, that the start date of the crediting period be delayed by more than one year but no more than 2 years by submitting to the secretariat a confirmation from a DOE that no changes have occurred which would result in a less conservative baseline and that substantive progress has been made by the project participants to start the project activity.*

8. With regard to provisions in paragraph 7(b) and (c) above, participants hosted by a Least Developed Country may:

(a) *Inform the secretariat to delay the start date of the crediting period by up to two years;*
(b) *[repeats paragraph 7(c)]*

10. Project participants may only make use of provisions of paragraph 7 or paragraph 8 once for each registered project activity.

This is a form of option; at the start of the crediting period, if the carbon price is low (high) and/or the project output is low (high), and the cost of CER verification and issuance is greater (less) than the CER value, the project proponent can defer (bring forward) making a claim for CERs up to 2 (1) years. However, this only applies at the start of the crediting period, and is once off. This paper is proposing that the option to claim or not claim CERs should be available throughout the entire crediting period, at the discretion of the project proponents, and not just at the start of the crediting period.

It is suggested that rules similar to that already existing, and quoted above (UNFCCC, 2015e) could be introduced. Such rules would not impact any other existing CDM rules.

4.3. Related issue

An issue, related to the one discussed in this paper, is the choice of crediting period. A project can either have a single 10-year crediting period, or a 7-year crediting period that can be renewed twice, giving a total of 21 years (Baker and McKenzie, 2015). If a 7-year crediting period is renewed, it must first be approved by the EB, and this requires, amongst other things, an updated PDD with the latest version approved baseline methodology and validated by the DOE.

The choice of an initial 7-year crediting period, and the subsequent renewal or non-renewal for a following 7 or 14 years, might be seen as a sequential option, that is an option to discontinue or continue as a CDM project at the end of year 7, and later possibly at the end of year 14. The analysis of the option occurring at the end of year 7 (assuming renewal only for one more 7-year period) is calculated in terms of the anticipated carbon-based costs (CDM operational costs) and anticipated carbon-based revenues (based on forecast CER prices and forecast project CER output) for years 8–14. All these costs and revenue contain uncertainty. This option value then needs to be compared with its ‘premium’, namely the (additional) cost of preparing an updated PDD at the end of year 7. The option value would need to exceed the additional PDD cost in order to proceed as a CDM project. That is, there could be value in having flexibility to either discontinue or continue a project at the end of year 7, dependent on anticipated costs and anticipated revenue at year 8 and over the following years up to year 14.

Similarly, if the choice at the end of year 7 is that of continuing CDM registration, there exists an option at the end of year 14. The value of this option is calculated in the same way as for the option at the end of year 7, where now the cash flows relate to anticipated carbon-based costs and anticipated carbon-based revenues for years 15–21. This option value then needs to be compared with its ‘premium’, namely the (additional) cost of preparing an updated PDD at year 15. Again, there could be value in having flexibility to either discontinue or continue a project at the end of year 14, dependent on anticipated costs and anticipated revenue at year 15 and over the following years up to year 21.

The total option value of having options at the end of both years 14 and 7 is evaluated by working backwards in time. The option value at the end of year 14 is calculated based on the cash flows in years 15–21. This option value, together the additional PDD cost at year 15 and the cash flows in years 8 to 14, give the option value at the end of year 7. This option value, together the additional PDD cost at year 8 and the cash flows in years 1–7, give the option value at year 0. This is the total option value and is compared with the up-front CDM cost in order to establish CDM viability.

This interpretation of the 3 by 7-year sequential option adding value to CDM projects is original.

5. Conclusion and policy implications

The paper proposed that options be allowed within CDM projects. Introducing options will require a CDM rule change. It is suggested that rules similar to CDM rules already existing, and quoted in Section 4 above (UNFCCC, 2015e), could be introduced. Such rules would not impact any other existing CDM rules. This idea of allowing options within CDM projects is original.

An option gives the project proponent the right but not the obligation to gain should the going price of CERs and/or the project CER output generated be favourable. The uncertainty associated with future CER prices, project CER output and costs are turned to the investor's favour. Two registered CDM projects, used as case examples, demonstrated the benefits of allowing options.

Allowing options within CDM rules improves the attractiveness of CDM projects. In turn, this should lead to more CDM projects contributing to sustainability via more emission reductions. It is seen that allowing options comes at no detriment to any stakeholder. It is a win–win situation – global emissions are reduced further by making more CDM projects viable, while project proponents potentially could gain financially, or lose less.

5.1. Related projects

The paper's conclusions carry over to related initiatives, such as the Carbon Farming Initiative (CFI) (Department of the Environment, 2015). CFI projects can also be demonstrated to be more attractive if options are allowed. Currently, as with CDM projects, options are not possible.

5.2. Future research

It is conceivable that, if available, options might only be exercised on many projects when the carbon price is high, and not when the carbon price is low, even though exercising is also dependent on individual project CER output. This could alter the supply-demand balance of carbon credits, and in turn affect the carbon price. This supply-demand-price relationship could be explored.

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