WIN-WIN? OR WIN-LOSE...?

GAME THEORY AND DECISION ANALYSIS APPLIED TO THE CASE OF SOLAR PV INVESTMENTS IN INDONESIA UNDER THE CDM

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Preface

This thesis is a contribution to the wider research project “Small is Beautiful?” which aims to identify the barriers and needed qualities of small-scale renewable energy projects in making them beneficial both for economic and environmental reasons. The project is a joint cooperation between the Department of Economics and Resource Management (IØR) at the Norwegian University of Life Sciences (UMB), the independent research agency FNI, and Differ AS, a private investment company specializing in small-scale technologies for reducing greenhouse gases. The main financer is the Norwegian Research Council. The research process included a field trip to Jakarta in March/April 2011.

Two more students – Tiril Reutz and Camilla Fulland – have been writing their theses as part of the same project. All three students have had the same topic in the sense that we all have been writing about the Indonesia as a country case. There has not been any collaboration in writing. However, we have collaborated in conducting interviews as part of the field work in Indonesia, and we have also practiced informal exchange of information sources, and we have swapped drafts in order to keep ourselves oriented on the work of the others.

Great thanks to my supervisor Eirik Romstad for being both demanding and understanding enough, and for always taking the time to answer any and all questions. Also, thanks go to Kristian Tangen, whose presence in the project has inspired an extra focus on the investor perspectives regarding the CDM.

Our interview subjects cannot be thanked enough: Dr. Terry Lacey, Dr. R. M. Sodejono Respati, Fabby Tumiwa, Eivind S. Homme, Constantin N. Karame, Dr. Irhan Febijanto, Agus Sari, Hari Yuwono, Anders Cajus Pedersen, Timothy H. Brown, Ishmid Hadad and Arnfinn Jacobsen. Thanks for taking the time, to all of you.

Thanks are also due to Mark Pop and Tess for lending out shelter, time, transportation and local expertise in Bali.

Special thanks to Tiril Reutz and Camilla Fulland for good companionship while travelling across the world and for being supportive – I hope I have given you the same! Also thanks to Erik Flaa for inspiration and guidance at a critical time in the process.

Ole Christian Albert at Statkraft deserves a special place in heaven for taking the time to do the impossible (a.k.a. to help an economist understand technicalities). I couldn’t have done it without you!

And last, but not least, thanks to my family and friends for tolerating my constant absenteeism the last three months, and to my better half Siri Lundsett for keeping control in the chaos and reminding me to eat, sleep and be a human being every once in awhile. I love you, and for what it’s worth, this one is for you.

Oslo, May 16th 2011

Erlend Aas Gulbrandsen

Abstract

Renewable energy technologies are considered an important instrument in achieving the double goals of sustainability and cost-effective abatement contained in the Clean development mechanism. However, previous studies indicate that the Clean development mechanism needs renewables more than renewables need the Clean development mechanism. This thesis investigates the relationship further by construction a four-leveled NPV model for the specific case of a small-scale solar photovoltaic power plant project in Indonesia. Special emphasis is put on the micro-level incentives of the players involved and how the incentives align. In addition, the effects of risk regarding project outcome and the possibility of CDM rejection are investigated. Conclusions support previous research in the fact that the impact of Clean development mechanism revenues on renewable energy technologies in general and solar photovoltaic plants in particular is limited. Further, it is uncovered that the incentives of the players do not necessarily align smoothly. Finally, some policy implications of the results are discussed.

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Abbreviations

CBA	cost-benefit analysis
CDM	the Clean development mechanism
CER	certified emission reduction
EB	the CDM Executive Board
EUA	European Union allowances
GHG	greenhouse gas
GOI	government of Indonesia
IPCC	International panel on climate change
NPV	net present value
PI	profitability index
PT PLN	the stated own power monopoly in Indonesia
PV	photovoltaic
REDD	reducing emissions from deforestation and forest degradation
RE	renewable energy
RET	renewable energy technology
SCC	social cost of carbon
SDR	social discount rate
UNFCCC	United Nations Framework convention on climate change
WTP	willingness to pay

1. Introduction

Evidence supporting the consensus that we are facing a crisis due to manmade climate change is mounting (see e.g. Pachauri & Reisinger 2007), making the importance of the task of mitigation on a global scale ever clearer. The Kyoto Protocol currently comprises the only available tool in the fight for internationally coordinated mitigation of climate change. However, only the Annex 1 countries have agreed to binding emission targets through the Kyoto protocol (UNFCCC 1998). Leaving out the problem of those developed countries that so far have refused to ratify the Kyoto protocol[1] the emissions from the developing nations (or non-Annex 1 countries, as they are termed) pose another major obstacle for achieving sufficiently large GHG emission reductions to fight climate change. Case in point, the non-OECD countries' share of world total GHG emissions increased from 34.2% in 1973 to 57.0% in 2008 (IEA 2010, p 6). Most of the responsibility for this shift must be accredited to the Asian economies, which increased its share of total GHG emissions from 8.7% in 1973 to 32.6% in 2008, with China as the biggest contributor to the increase (ibid). But China is not the only big emitter in Asia. Indonesia is an example of a major but often overlooked perpetrator, estimated to account for 7% of world's total GHG emissions in 2009, and with a projected growth in GHG emissions of 30% between 2005 and 2020 in a business-as-usual (BAU) scenario (Ministry of Finance 2009, pp 19-20).

The Clean Development Mechanism (CDM) is currently the only part of the Kyoto protocol that deals with the emissions of non-Annex 1 countries[2]. And, excluding REDD (Reducing Emissions from Deforestation and forest Degradation), which still is in its early stages as far international level implementation goes[3], the CDM is at present the only broadly coordinated effort by the international community to curb emissions from and ensure sustainable development in the developing nations. With this in mind, and with the commitments of the Kyoto protocol drawing to an end in 2012, still without any clear successor in the pipeline (Romano & Burleson 2011), it comes as no surprise that there is an abundance of recent

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[1] Currently only the USA (UNFCCC 1998), but this is no small problem, as the USA is by far the largest emitter of GHGs among the Annex 1 countries (UNFCCC 2011a).

[2] The Kyoto Protocol consists of emission caps and trading between Annex 1 countries, and the two flexible
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mechanisms JI and CDM, of which CDM enables projects reducing GHG emissions in developing nations to be used to offset Annex 1 emissions. (see e.g. (UNFCCC 2011b)).

[3] Although pioneering nations such as Norway are already making REDD-partnerships, the coordinated UNFCCC effort on the matter as per the Cancún summit has come no further than to make a general agreement on the need to slow the loss of forest (Romano & Burleson 2011).

research regarding the nuts and bolts of the CDM, with plenty of helpful suggestions regarding the direction and the future life of the mechanism.[4]

Under the CDM umbrella renewable energy technologies (RETs) are a special area of focus in the literature, due to their potential in general for mitigating GHG emissions (Dincer 2000), and their potential in specific for combining the two main goals of the CDM, sustainable development and cost-effective GHG abatement[5] (ibid). However, the use of CDM for the diffusion of RETs presupposes that the CDM works as a tool for both achieving the double goals of sustainable development and least cost GHG abatement. The merits of the CDM in this respect are contested. More on this issue can be found in the section 2.1.

On an even more fundamental level, the self-interests of four different types of players – the Annex 1 country that is buying the CERs, the non-Annex 1that is hosting the CDM project, the private, foreign investor supplying the capital, and the investor’s local business partner – have to overlap to some extent in order for the CDM function. This required alignment is illustrated in figure 1 below. This figure also illustrates the fact that the investor’s interests can be viewed as a subset of Annex 1 country interests, and similarly that the interests of the investor’s local partner are a subset of the host country interests.

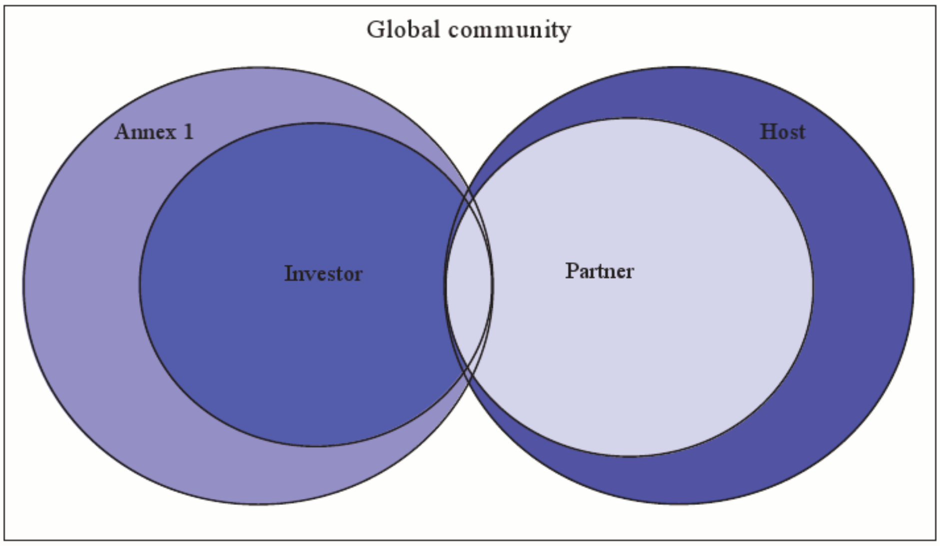

Figure 1.1: Schematic sketch of Venn diagram on player interests in CDM-projects.

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[4] Paulsson (2009) offers a thorough review of this literature.

[5] Article 12.2 of the Kyoto Protocol defines the purpose of the CDM as being “to assist Parties not included in Annex I in achieving sustainable development and […] to assist Parties included in Annex I in achieving compliance” (UNFCCC 1998, p11).

However, the question is open as to both the size and the existence of the interest overlap, as the differences in motivation between the four players are evident from just a quick glance at the motivations of the different players. The Annex 1 countries are involved in the CDM game looking for least-cost carbon abatement[6]. The host countries on their part are in the game looking for sustainable development and funding, perhaps even without any direct interest in mitigation by itself, as is the case for Indonesia (Hadad 2011). The private foreign investors are simply in the game to earn profits[7]. And although the local business partners might have some of the same motivation as the foreign investor, in the sense that they are seeking profits, these profits are likely to come, to some extent, from the same slice of pie as the profits of the investor, something which makes for possible conflicts.

To make matters even more complicated, there is, as illustrated in the figure, also a fifth player involved in the CDM game – the global community as a whole. The whole justification of the existence of the CDM is essentially based on the assertion that the interplay between the (hopefully) overlapping self-interests of the four active players, coordinated by the market mechanism known as the CDM, results in an equilibrium that serves the objective interests of the global community as a whole when the sum of all market and non-market effects are considered.

Taking into account the differences in motivation between the four active players in the game, and considering the complexity of the interplay between all five players as a whole, it is surprising that not much work has been put into investigating the alignment of the self interests of the different types of players involved in the CDM. This gets even more surprising when viewed together with the fact that the carbon market and the CDM market in themselves are artificial constructs made in order to deal with the, in all likelihood, greatest externality humanity has ever faced (Stern 2007). This is not to say that game theory is absent from the Kyoto-related literature. Nothing would be further from the truth. But the incentives that have been investigated are chiefly, although there are some exceptions, those of parties negotiating

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[6] This follows naturally if we, as good economists, assume that the Annex 1 countries are rational and selfish economic agents.

[7] Again, if we apply rationality, along with profit maximization, this result is evident. However, a fraction of firms might be looking for the PR effects of being "green", and thus be interested in sustainability without profit as their primary goal. This type of motivation is outside the scope of this thesis, and the fraction of "green" firms will for the rest of this thesis be assumed to be zero. Interested readers are referred to Laufer (2003) for an exposition of why the "green motivation" might not give as green results as one might hope.

the Kyoto protocol itself or its successor, through a game theoretic approach. For more details on this and on the relevant literature on the CDM in general, see the literature section.

This thesis aims to investigate the alignment of the interests of the different CDM players in depth by looking at the concrete case of an *ex ante* valuation of a small-scale solar PV plant project in Indonesia. The interests of the players are represented economically by conducting a rough CBA from the point of view of the different players, using appropriate market and non-market cash flows over the project lifetime. More specifically, the CBAs are conducted at four different levels of analysis: the global level (seen from the point of view of a benign supra-national principal), the Annex 1 level (seen from the point of view of a generic Annex 1 country), the host nation level (seen from the point of view of the Indonesian community) and the investor level (seen from the point of view of a generic private investor originating from an Annex 1 country). The interests of the investor's local partner is not studied directly in this thesis, but rather just included in the host country level of analysis. This is mainly due to the fact that the cash flows accruing to the investor's local partner are somewhat elusive, as they will be largely dependent on the deal structure between the local partner and the investor.

The research questions (RQs) are:
RQ1: When does investment in a typical small-scale solar PV-power plant in Indonesia yield profitability

   a. *from a foreign investors perspective?*
   b. *from an Indonesian perspective?*
   c. *from an Annex 1 country's perspective?*
   d. *from a global perspective?*

RQ2: Which parameters are most influential on the results in RQ1?

RQ3: Given the results in RQ1 and RQ2, are there any obvious conflicts of interest between players?

RQ4: To what extent do the cash flows related to the Clean Development Mechanism (CDM) influence the results in RQ1?

RQ5: How does uncertainty regarding project outcome and CDM approval affect the payoffs of the four different players?

RQ6: Given the answers to the above questions, which policy instruments may be used to correct for any discrepancies between the different levels of analysis?

On a final note, solar PV should provide a good case for highlighting renewable energy projects in the CDM framework, as it currently seems to be the least profitable type of RET to be found in the CDM framework (Schneider et al. 2010), but at the same time it shows promise of a huge future potential on a broad scale – the cumulative installed solar PV capacity worldwide has increased six fold between 2004 and 2010, and experts expect even higher growth in the coming years (REN21 2010, p 19). As for Indonesia, the nation should be both an interesting and a relevant host case, as it exhibits an interesting mix of both very attractive aspects[8] and rather unattractive aspects[9] as far as foreign investors are concerned.

The rest of the thesis is structured as follows: Section 2 gives an overview of the relevant literature, with focus on any debated topics and/or methods referred to in the rest of the thesis (that is: general overview of obvious topics is skipped). Section 3 presents the methodology used in the thesis, more specifically the CBA-alternatives, the methods of sensitivity analysis, and a framework for handling uncertainty. Section 4 gives a bird's eye view of the data used for the NPV-quantification (the data in detail can be found in section 9.3). Section 5 presents the quantification results, while section 6 discusses the results and section 7 presents answers to the RQs and concludes the thesis.

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[8] Mainly the facts that the economy is large and that electricity needs are growing fast, along with rest of the economy (Pedersen 2011).

[9] Weak institutions and a high degree of corruption (Henderson & Kuncoro 2011) are the main problems.

2. Literature

This section discusses the main works in the literature that have direct relevance to the issues put forth in the thesis. The discussion is not meant to be an exhaustive reference on all the practical and theoretical concepts used or referred to in the thesis, but rather it aims to put focus on the papers to which my analysis owes the most, and also shed some light on my choice of side in subjects that still are subject to disputes in the international academic debate.

2.1. The Clean Development Mechanism (CDM)

The CDM is, as has already been briefly mentioned in the introduction, the only one of the Kyoto Protocol's three flexible mechanisms that deals in any way with the emissions of the developing countries (UNFCCC 1998). Though the mechanism itself is anchored in the Kyoto Protocol, the detailed rules and procedures needed to govern it were finalized before the Meeting of the Parties in Marrakesh in 2001 (Paulsson 2009). As the developing countries, or non-Annex 1 countries, are exempt from any cap on their GHG emissions (Paulsson ibid), the CDM is effectively the only tool apart from the REDD initiative that currently might be used to curb the emissions of the developing countries. This fact has given rise to a major strand of literature discussing the CDM and its virtues, its imperfections and its potential. This literature is reviewed by Paulsson (2009).

The main themes discussed in the CDM literature, as presented in Paulsson (2009), are: how to secure additionality, baseline definition, leakage and permanence, sustainable development, and the future of the mechanism. Paulsson (2009) further states that in her view, too many of the articles she reviews take the existence of the CDM in its current form as a given, and put their primary focus on fine-tuning the mechanism rather than subjecting the mechanism as a whole to critical scrutiny. I shall commit the opposite sin. In the remainder of the thesis I will take for granted that the CDM is well-functioning in its details: I will assume that the additionality criteria currently used by the CDM Executive Board (EB) are working properly, though evidence from the literature might question this (Bode & Michaelowa 2003; Zhang & Wang 2011); I will take for granted that the demanding exercise known as baseline definition is unproblematic, though it clearly is not (Fischer 2005; Kartha et al. 2004); I will consider leakage to be non-existent and permanence to be assured, though convincing arguments say the risks of the opposite are most definitely real (Murray et al. 2004; Schwarze et al. 2002)[10]; I will take on good fate that some sort of sustainable development will be achieved through the deployment of CDM projects, though many argue to the contrary (Boyd et al. 2009; Flamos 2010; Lloyd & Subbarao 2009; Sutter & Parreño 2007); and last, but not least, I will, contrary to the wisdom of others (Boyd et al. 2009; Michaelowa et al. 2005; Sterk & Wittneben 2006), take the future existence of the CDM in its current form for granted. It is my hope, however, that through committing all these breaches of protocol, I shall be able to put focus elsewhere and say something meaningful about other underlying forces affecting the CDM even when the nuts and bolts of the mechanism are functioning smoothly, namely the micro-level incentives of the actors involved. In turn I hope to use the insights gleaned to hint at the general viability of the CDM as an instrument in the struggle to reduce GHG emissions.

Although my choice of focus excludes much of the literature on CDM, there are still some strands of literature that are relevant to this thesis. These are: the literature on the deployment of RETs under the CDM; the literature on transaction costs in the CDM; and literature with a game-theoretic focus on international environmental issues in general and on the Kyoto protocol in particular. I will now discuss these strands of literature in turn.

Regarding the first type, the literature discussing RETs in the CDM framework, it is quite dense. Schneider et al. (2010) defines three different sub-streams of literature dealing with the diffusion of RETs through the CDM: first, literature that conceptually analyzes the drivers and barriers of the CDM; second, literature that analyzes general aspects of host-country attractiveness; and third, literature that undertake project-level economic analysis in the CDM. The distinction seems fruitful, and of these three sub-streams, only the third one is directly relevant for to the thesis. Most of the articles within this type of literature seem to deal with just the simple question of profitability or investment outlooks from an investor's viewpoint. The tools used range from simple NPV analysis, via multi-criteria analysis to purely technical feasibility studies, and as a rule the studies are done without any further consideration of neither the decision making process of the investor, nor the gains for any other actors. The list includes, but is not limited to Diakoulaki et al. (2007), Duic et al. (2003), Georgiou et al. (2008), Kishore et al. (2004), Purohit (2008), and Ruan et al. (2007).

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[10] Both of these papers investigate carbon leakage in a forestry perspective, and both of them conclude that leakages are likely to be a problem in other sectors as well, such as energy.

Some articles in the above literature strand stand out as more relevant than the others. Prengel (2004) puts focus on risk related to wind projects under the CDM and discusses some options for risk mitigation. However, the focus is mainly on the technical aspects of windmill construction, and he only categorizes the risks qualitatively, without doing any treatment of the microeconomic consequences of risk. Resnier et al. (2007) use a two-part optimalization model to determine the optimal level of taxes and subsidies related to the CDM in China, from the point of view of China. The goal is to secure a good balance between sustainability and profitability, creating the greatest possible sustainability impact while ensuring investor interest in CDM projects in China, and the papers conclude by recommending a very specific set of policy instruments, consisting of tax on HFC-projects and subsidies on the most promising RETs (Resnier et al. 2007).

Finally, the paper by Schneider et al. (2010) has already been cited earlier in this thesis, and warrants some extra attention here, as the approach in the paper is on many accounts very similar to the one used in this thesis. Schneider et al. (2010) investigate the performance of six different RETs in the CDM. Both the financial performance in terms of NPV for an investor and the environmental performance of the RETs are evaluated, with the environmental performance measured in *specific GHG reductions*[11]. The main focus of Schneider et al. (2010) is to use simulation to identify which factors are the most influential on RET performance, and generic input conditions for global, regional and project-specific variables are used as the starting point for these simulations. The main findings in the paper are that regional conditions matters most for PV, but that PV is always unprofitable under the assumptions made. The authors recommend introducing multiplication factors for PV and other types of desirable but unprofitable RETs, in order to increase CER payments for these technologies.

The astute reader will already have identified several similarities and dissimilarities between this thesis and the paper by Schneider et al. (2010). To tackle the similarities first, the use of a multilevel performance analysis is probably the most striking one. As outlined below, however, the choice of levels of analysis owes more to Lee et al. (1997) than to Schneider et al. (2010). Further, similarities include the use of NPV as an indicator for financial

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[11] *Specific GHG reductions,* as defined in Schneider et al. (2010), is the GHG emissions that a project saves during its entire operational lifetime, divided by the invested capital. This measure is closer to the realm of cost-effectiveness analysis than that of CBA.

performance, and the use of scenario based sensitivity analysis to elicit the main drivers behind the performance conclusions. As for the dissimilarities, the main one is that this thesis focuses more explicitly on a micro-level treatment of the decisions of the players, with a special focus on the effect of risks. Further, there are three additional differences when it comes to method. First, the analysis in this thesis is technology and country specific, and so achieves a greater level of detail in both the types of effects that apply and the estimates used to quantify these effects. Second, the analysis in this thesis includes two national levels of analysis, and thus looks at four levels of analysis, as compared to the two levels used by Schneider et al. (2010). The inclusion of the national levels of analysis allows for a closer investigation of the dynamics between the nation states and the global community in the CDM game. Last, the policy measure used at the global level of analysis in this thesis is the NPV, as opposed to the specific GHG reductions used by Schneider et al. (2010). This allows for a more informed comparison of the benefits on the different levels of analysis.

Turning the focus towards the strand of literature on transaction costs (TCs) in the CDM[12], two papers stand out. The first these is Michaelowa et al. (2003), which presents the most thorough walkthrough of TCs in the CDM to date, including both a conceptual overview of the different types of TCs related to the CDM, and a detailed estimation of TCs in general and for specific project types. The paper concludes that TCs are especially tough to bear for small-scale projects, as the TCs are not linearly related to project size, something which gives rise to economies of scale in CDM projects. The second the relevant papers is Michaelowa and Jotzo (2005) which builds on the work done in Michaelowa et al. (2003) and constructs a model for estimating supply and demand for emission permits (including both “hot air” AAUs and CERs from CDM), in order to determine how TCs affect the size of the CDM. They find that with increases in TC the volume of CERs traded is reduced, but the total CDM revenue will be roughly the same, due to the increased market price of the traded CERs (Michaelowa & Jotzo 2005). This thesis will, as detailed in section 9.3, use estimates taken from Michaelowa et al. (2003) to quantify TCs.

Finally, when it comes to literature with a game-theoretic approach to international environmental issues, the main focus has historically been on the outcomes and payoffs related to the negotiation of international environmental agreements. Barrett’s seminal paper

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[12] I will, in keeping with the style of the rest of the thesis, take the concept of TCs for granted here. For a more thorough walkthrough on TCs in the CDM, see Reutz (2011).

outlining climate negotiations where a pro-regulation coalition use Stackelberg leadership to force other parties into signing the treaty (Barrett 1994) is the prime example of the tradition, while de Zeeuw (2008) and Morath (2010) present more recent examples. However, as the theme dealt with in this type of papers is not directly relevant to this thesis, they will not be discussed further here. The subset of papers that applies game theory to the flexible mechanisms of the Kyoto protocol is a much smaller field, but more relevant here. In this genre it appears that much of the work relating to the incentives and interplay regarding the CDM has been done pre-Marrakesh. Lee et al. (1997) and Janssen (1999) represent the most relevant of the pre-Marrakesh papers, while Bréchet and Lussis (2006) represent the most relevant post-Marrakesh paper.

As for the pre-Marrakesh papers, Lee et al. (1997) deal with and argue against concerns raised by non-Annex 1 countries regarding the flexible mechanisms. The paper is largely non-technical, but the authors use basic game theory as framework for defining the content of the flexible mechanisms. Lee et al. (1997) define five players in the "JI" [13] game on individual project agreement: the global community, the investors, the host country partners of the investor, the investors' countries, the host countries. Except the fact that "host country partners" are named "local partners" in this thesis, the typography used is identical. Janssen (1999) investigates the problem of commitment in JI and CDM contracts by imposing a non-cooperative game setting, and concludes that in the absence of instruments to enforce cooperative behavior, neither the investing party or the host will honor their commitments, and thus the projects will not be realized. The paper suggests remedies to this problem, but these will not be discussed here, as they appear somewhat dated after the CDM procedures were agreed upon in Marrakesh. However, Janssen (1999) makes an important point about how bargaining power affects the required stream of revenue passed on from the investor to the host[14]. If ΔT denotes the gains to the investor[15] and C_{CDM} denotes the total costs to the host of implementing the project, then the payments from the investor to the host, denoted Θ, must fall within the range $\Delta T \geq \Theta \geq C_{CDM}$. The exact size of Θ will be decided by the relative bargaining power of the two players. Different notation will be used in this thesis, but the concept is utilized.

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[13] Throughout the paper, Lee et al. (1997) use "Joint Implementation (JI)" as a term covering both the flexible mechanisms.

[14] The paper does not make distinctions between the host country and the private local partners of the investor.

[15] The gains to the investor are represented by net saved carbon taxes in Janssen's framework, while in my framework it will be CER revenues.

Moving on to the post-Marrakesh literature, the relevant findings are even more meager. The most relevant paper, by Bréchet and Lussis (2006), use a partial equilibrium model to analyze the impact of the CDM on the national climate mitigation policy in Belgium, concluding that use of the CDM could shrink the cost of compliance to the Kyoto protocol by a factor of 10 in Belgium. However, this article only deals with the incentives of an Annex 1 type of player; the incentives of the other types of actors are left unexplored. That concludes the literature review on the CDM.

2.2. Cost-benefit analysis (CBA)

Cost-benefit analysis (CBA) as a method for policy evaluation is much used by environmental economists and social planners all over the western world[16]. As a reader service, here is a basic variant of the NPV equation as used in CBA:

$$NPV = -I + \sum_{t=1}^{T} \frac{1}{(1+\delta)^t}(B_t - C_t) \qquad [1]$$

Where I is intial investment, δ is the social discount rate (SDR), B_t is the stream of project benefits, and C_t is the stream of project costs. In financial NPV calculation δ is replaced with r, the private discount rate. Otherwise the model is identical.

There is not much debate on the NPV as method in itself. And in financial cash flow models, not much debate is to be had about the variables entering the equation either. Accounting cash flows are used for I, B and C. There are some differing preferences of which discount rate r, but it’s mainly just a friendly debate on which market rate to use, or whether to use the WACC (weighted average cost of capital) method. I will not go into these issues here, as they have little relevance for the main topics of the thesis. They are treated in

When it comes to CBA, on the other hand, two of the four main variables, B_t and δ, as well as some of the underlying foundations, are debated. Boardman et al. (2006) present the main criticisms against CBA as: skepticism against the utilitarian assumption in CBA that it is

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[16] Most industrialized countries have protocols demanding CBAs for different types of regulatory changes (Boardman et al. 2006).

possible calculate trade-offs between on person's benefits and another person's costs; disagreements on how to value (monetize) non-market impacts; and last, how to make trade-offs between the present and the future (the authors are implicitly referring to the controversies surrounding the choice of social discount rate). Turner (2007) specifies a certain area of the theoretical welfare economics foundations of CBA that is singled out for critique, and that is the concept referred to as the Kaldor-Hicks criterion or potential Pareto improvement[17]. Interested readers are referred to Turner (ibid) for a more thorough review. I will not discuss the matter further here, as it is too fundamental and philosophical in nature, and thus outside the scope of this thesis. When it comes to valuation of non-market impacts in general, and the method of contingent valuation in particular, Vatn and Bromley (1994) provide an interesting critique of the method. I will not dwell further on this issue either, as, again, it is too fundamental, and addressing it is both outside my area of expertise and outside the aim of the thesis.

That leaves the debate on discounting. Or, to specify, the practice of discounting as such is pretty uncontroversial, but the choice of social discount rate (SDR) has for quite some time now been a hot topic in the scholarly debate.[18] Most of the debating parties, however, seem to agree on the Ramsey rule as a good starting point for finding the theoretically correct SDR[19]. The groundbreaking work done by Weitzman (1998) might at first glance seem to represent a diverging view, but the conclusions in the paper have later been reconciled with the Ramsey rule by Gollier (2010). The Ramsey rule for the discount rate as presented in Anthoff et al. (2009) is:

$$SDR = \rho + \eta\, g \qquad [2]$$

Where ρ is the rate of pure time preference, g is the growth rate of per capita consumption and η is the elasticity of marginal utility of consumption.

As already mentioned, the rule seems to be agreed upon. But the tricky, and much less agreed upon, part, is how to estimate the different parameters featured in the rule. Stern (2008) and a

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[17] The Kaldor-Hicks criterion: a policy is justified if those gaining from the policy change *could* compensate those who bear the costs of the policy change and still be better off than before, regardless of whether compensation actually takes place.

[18] Anthoff et al. (2009) and Stern (2008) represent two recent examples of opposites in this debate.

[19] At least this seems to be the position found in Stern (2008), Anthoff et al. (2009), and Gollier (2010).

line of economists with him (Stern ibid) argue that both ρ and η can only rightly be determined as an ethical judgment done by the analyst, while Anthoff et al. (2009) represent the view that all the parameters in the rule can be determined empirically. That provides the essence of the debate, and although my exposition here does not give the issue the full level of depth and detail that it deserves, it serves my main point, which is to show that the method of CBA is contested, although I use it without reservations in my analysis. One more point worth noting is that I follow the approach of Anthoff et al. (2009), but find that the estimated SDR at the global level of analysis still falls well within the boundaries indicated by Stern (2008)[20].

I conclude this section with one final word of warning. Given the criticism outlined above, and the uncertainty attached to many of the estimates used in this thesis (see the data section for more on this), there is little doubt that the NPV results found must be quoted only with the utmost care. As such, the NPVs are not the goal in themselves here, but rather an important step of the way towards the sensitivity analysis. The sensitivity analysis is in turn used to inform policy recommendations through pointing out some main drivers behind the economic conclusions regarding the solar PV project. Luckily, this type of use of CBA, “as a component of a comprehensive policy analysis” (Turner 2007, p 254) demands somewhat less of CBA than when the NPV-ranking of projects is used directly as a decision rule for selecting projects or policies.

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[20] As indeed do Anthoff et al. (2009).

3. Methodology

The method of analysis used in this thesis borrows heavily from modern cost-benefit analysis (CBA), but due to the often mediocre quality of data describing developing nations, a full-blown CBA is not conducted. Time is instead devoted to a analyzing from the point of view several different levels in order to detect potentially counterproductive differences between these levels of decision making. Decision analysis is used to investigate how the players respond to uncertainty that do not stem from the strategic behavior of other players. And finally, concepts from basic game theory are used to provide a basic model for the dynamics of the CDM game.

This section lays out the details of the tools of analysis used in this thesis. Section 3.1 recaps the CBA methodology and explains the difference between standard CBA and the "rougher" approach taken here. Section 3.2 looks closer at the building blocks in the NPV model, while section 3.3 investigates micro-level incentives, and section 3.4 outlines the methods used for sensitivity analysis on the quantitative results.

3.1: CBA methodology

Although this thesis makes use of modern CBA, the framework of a full-blown CBA is not used. To quickly recapitulate, the steps of modern CBA, as they are identified in Boardman et al. (2006):

1. Specify the set of project alternatives
2. Decide who has standing, i.e. who the stakeholders are
3. Catalogue impacts and select measurement indicators
    a. Keep track of distributional effects (groups of "winners" and "loosers")
4. Predict impacts quantitatively over the project lifetime
5. Monetize impacts
6. Discount benefits and costs to obtain present values
7. Compute the net present value of each alternative
8. Perform sensitivity analysis
9. Make a recommendation

Source: Boardman et al. (2006, pp 7-17)

Of these steps, most are performed to some extent, but step (3) and (4) is not explicitly done for all elements in the analysis, as I do not calculate the physical impacts and of all elements in the analysis, but rather use monetized estimates from the literature directly. The SCC and the health effects of the diesel aggregates are the prime examples of this.

Distributional issues within the boundaries of each player are not kept track of in any way, for the sake of simplicity.

3.2. NPV model building blocks

3.2.1. Players and motivation

The private investor:
Only the firm of the imaginary private investors that owns the PV project has standing on this level of analysis, and only the flows of accounting costs and revenues accruing to this firm are counted.

The host country:
Only citizens of the host country have standing on this level of analysis. But the perspective is social, as in the global level of analysis. The flow of costs and benefits are somewhat changed from the global perspective, however, as effects that accrue to members of the global community that are situated outside the host country are disregarded.

The Annex 1 country:
The perspective is social, but only the citizens of the host country have standing.

The global community:
The perspective is social, and *all* individuals in the world have standing in the analysis. As the perspective is social, only real, economic costs and benefits are counted. Or, put differently, money changing hands between individuals with standing are disregarded, costs are viewed strictly as opportunity costs compared to the null alternative, benefits are the results of beneficial effects not found in the null alternative, and special attention is paid to the non-market costs and benefits, as is common in modern CBA (see e.g. Boardman et al. 2006).

3.2.2. Placement alternatives

In this subsection, three alternatives regarding the placement of the PV power plant are constructed, and these are used across all the levels of analysis as project alternatives for all the four players.

Grid connected power supply: The PV power plant delivers power to a national grid in Indonesia, such as the Java-Madura-Bali grid (see e.g. IEA & OECD (2008) p 173 for a map of this grid). In shorthand this scenario is referred to as the "grid alternative" in the rest of this thesis.

Local power supply displacing diesel generators: The PV power plant delivers power to end-users in a number of villages through a web of already existing distribution lines set in place for village level diesel power generators. The scenario implies linking together the sufficient number of villages in order to get the desired quantity of demanded electricity. Depending on local distances and the size of the PV power plant, this might require the construction of some amount of transmission lines. This scenario is referred to as the "diesel alternative" in shorthand in the rest of this thesis.

Local power supply to villages previously without electricity: The PV plant delivers power to end-users in a number of villages that previously had no supply of electricity available. This means that in addition to the need for new transmission lines, all distribution lines has to be built, as none of this infrastructure is in place to begin with. In shorthand referred to as the "no grid alternative" in the rest of this thesis.

The plausibility of a diesel or no grid alternative is strong, as according to several sources in the literature, a large part of the Indonesian community is without access to the central grids. Draeck (2008, p 13) estimates that there are 6,000 villages that will not be reached by the national electrification grid in the near future.

3.2.3. Null alternatives

The placement alternatives are one matter, but in order to employ CBA as a method of analysis we also need a null alternative of business as usual (BAU) where the investment never takes place. With a total of 12 NPVs to calculate (three placement alternatives times four players), there are many alternatives to cover. A brief schematic table gives some perspective on the construction:

Table 3.1: Hierachy of null alternatives.

Global null alternative				
Investor null	***Host null***			***Annex 1 null***
BAU	*Grid BAU*	*Diesel BAU*	*No grid BAU*	*BAU*
- Alternative use of investment capital.	- Investment in coal power plants	- Keep on running diesel	- Investment in coal power plants	- Emission reduction covered through EU ETS trading - Alternative use of investor capital.

Table 3.1 illustrates the fact that the global community null alternative is comprised of all the other level null alternatives. It also contains some elements of global community BAU that falls outside the spheres of the three other players, such as the alternative use of CDM-staff time. For simplicity, multiplier effects of money gained or lost are ignored across all players and for all benefit and cost elements.

Below a short summary of the null alternative situation is provided for each player.

Investor null alternative

The investor null alternative is simply not to invest in the solar PV project in Indonesia. It is further assumed that the investor has other projects that can earn her or him standard market rate of return. As per standard corporate finance (see e.g. Berk & DeMarzo 2007), this is reflected in the discount rate the, which demands the market rate of return on risk free assets plus a project-specific risk premium.

Host country null alternative

This null alternative contains some information specific to Indonesia, namely the urgent need for increased supply of electricity and increased security of electricity supply (large parts of Indonesia suffer from daily blackouts and brownouts), that results in the assumption that a solar PV plant is seen reducing the need for Indonesian electricity investments at the margin, creating a benefit for the host country in the form of reduced investment costs. Investments from the GOI are not assumed to flow to sites that already have diesel generators supplying power, so the benefit of reduced investments does not accrue there. But, as diesel generators are reducing the local air quality through particle pollution, there is instead a strong health benefit from replacing diesel generators.

Annex 1 country null alternative

The null alternative for the Annex 1 country is that the Annex 1 country has to buy more costly EUAs (EU ETS permits) or abate at home.

Global community null alternative

The global community null alternative consists, as illustrated above, of the sum of the all the other players' null alternatives. In addition, the null alternative here recognizes the OCs of CDM-staff's time, and incorporates the costs of potentially non-additional CERs being awarded to the solar PV project.

That concludes the brief overview of the null alternatives. For more in-depth information, and tables with detailed overviews over the 12 null alternatives and their corresponding effects on each of the 12 NPVs, consult section 9.2.

3.2.4. NPV equations

This section collects the NPV model equations for all players and placement alternatives, for a total of twelve NPV calculations collected in three equations – one equation for each player studied.

A quick explanation of format is due before the equations themselves are displayed. Individual NPVs are presented in the form NPV_{ij} where i signifies which player and j signifies which placement alternative is active, while the bold face form $\boldsymbol{NPV_i}$ signifies the vector consisting of all placement alternative NPVs for player i. As for the elements in the equations, costs, both market and non-market, are on the form C_{ijt}^{txt}, where *txt* is replaced by text indicating the type of cost, while i and j have the same meaning as for the NVP, and t is the time index, running from zero to terminal time T. The revenue elements for the private investor are on the form R_{ijt}^{txt} and the benefit elements for the global community and the countries are on the form B_{ijt}^{txt}. The exact meaning of the indexes i and j is:

$$i \,\forall \begin{Bmatrix} 1 = investor \\ 2 = host \\ 3 = Annex\ 1 \\ 4 = global \end{Bmatrix} \qquad [\ 3]$$

$$j \,\forall \begin{Bmatrix} 1 = grid \\ 2 = diesel \\ 3 = no\ grid \end{Bmatrix} \qquad [\ 4]$$

As for the setup of the equations, in each equation, elements that are on the same column all have the same numerical value. Boldface signifies that the element is a vector. Elements in red text are elements that will be left as unquantified effects.

See next page for the equations.

$$\boldsymbol{NPV_1} = \begin{bmatrix} -C_{110}^{plan} - \sum_{t=0}^{t_{start}} \left(\alpha^t \, TC_{11t}^{indo}\right) - \sum_{t=0}^{\tau} \alpha^t (\; TC_{11t}^{cdm}) + \sum_{t=t_{start}}^{T} \alpha^t (\; R_{11t}^{el} \; +R_{11t}^{cdm} \; +R_{11T}^{hor} \; -C_{11t_{start}}^{build} \; -C_{11t}^{maint} \; -C_{11t}^{land} \; -TC_{11t}^{op} \;) \\ -C_{120}^{plan} - \sum_{t=0}^{t_{start}} \left(\alpha^t \, TC_{12t}^{indo}\right) - \sum_{t=0}^{\tau} \alpha^t (\; TC_{12t}^{cdm}) + \sum_{t=t_{start}}^{T} \alpha^t (\; R_{12t}^{el} \; +R_{12t}^{cdm} \; +R_{12T}^{hor} \; -C_{12t_{start}}^{build} \; -C_{12t}^{maint} \; -C_{12t}^{land} \; -TC_{12t}^{op} \;) \\ -C_{130}^{plan} - \sum_{t=0}^{t_{start}} \left(\alpha^t \, TC_{13t}^{indo}\right) + \sum_{t=t_{start}}^{T} \alpha^t (\; R_{13t}^{el} \; +R_{13T}^{hor} \; -C_{13t_{start}}^{build} \; -C_{13t}^{maint} \; -C_{13t}^{land} \; -TC_{13t}^{op} \;) \end{bmatrix}$$

Eq. [5]. *Investor NPVs.*

$$\boldsymbol{NPV_2} = \begin{bmatrix} \sum_{t=0}^{t_{start}} \beta^t \left(B_{21t}^{tax} - OC_{21t}^{indo}\right) + \sum_{t=t_{start}}^{T} \beta^t (\, B_{21t}^{learn} \; +B_{21t}^{empl} \; +B_{21t}^{tax} \; +B_{21t_{start}}^{invest} \; -C_{21t}^{el} \;) \\ \sum_{t=0}^{t_{start}} \beta^t \left(B_{22t}^{tax} - OC_{22t}^{indo}\right) + \sum_{t=t_{start}}^{T} \beta^t (\, B_{22t}^{learn} \; +B_{22t}^{empl} \; +B_{22t}^{tax} \; +B_{22t}^{heal} \; -C_{22t}^{el} \;) \\ \sum_{t=0}^{t_{start}} \beta^t \left(B_{23t}^{tax} - OC_{23t}^{indo}\right) + \sum_{t=t_{start}}^{T} \beta^t (\, B_{23t}^{learn} \; +B_{23t}^{empl} \; +B_{23t}^{tax} \; +B_{23(t_{start}+10)}^{invest} \; +B_{23t}^{el} \; -C_{23t}^{el} \;) \end{bmatrix}$$

Eq [6]. *Host NPVs.*

$$\boldsymbol{NPV_3} = \begin{bmatrix} NPV_{11}^{\gamma} + \sum_{t=t_{start}}^{T} \gamma^t \, R_{11t}^{cdm} + \sum_{t=t_{start}}^{T} \gamma^t (\; B_{31t}^{abate} \;) \\ NPV_{12}^{\gamma} + \sum_{t=t_{start}}^{T} \gamma^t \, R_{12t}^{cdm} + \sum_{t=t_{start}}^{T} \gamma^t (\; B_{32t}^{abate} \;) \\ NPV_{13}^{\gamma} \end{bmatrix}$$

Eq [7]. *Annex 1 NPVs.*

$$\boldsymbol{NPV_4} = \begin{bmatrix} -C_{110}^{plan} & -\sum_{t=0}^{t_{start}} \lambda^t \left(OC_{21t}^{indo} + TC_{11t}^{indo}\right) & -\sum_{t=0}^{\tau} \lambda^t \left(OC_{41t}^{cdm} + TC_{11t}^{cdm}\right) & + \sum_{t=t_{start}}^{T} \lambda^t (& B_{41t}^{sum} & & & -C_{11t}^{sum} & -C_{41t}^{scc} &) \\ -C_{120}^{plan} & -\sum_{t=0}^{t_{start}} \lambda^t \left(OC_{22t}^{indo} + TC_{12t}^{indo}\right) & -\sum_{t=0}^{\tau} \lambda^t \left(OC_{42t}^{cdm} + TC_{12t}^{cdm}\right) & + \sum_{t=t_{start}}^{T} \lambda^t (& B_{42t}^{sum} & +B_{22t}^{heal} & & -C_{12t}^{sum} & -C_{42t}^{scc} &) \\ -C_{130}^{plan} & -\sum_{t=0}^{t_{start}} \lambda^t \left(OC_{23t}^{indo} + TC_{13t}^{indo}\right) & & + \sum_{t=t_{start}}^{T} \lambda^t (& B_{43t}^{sum} & & +B_{23t}^{el} & -C_{13t}^{sum} & &) \end{bmatrix}$$

Eq [8]. *Global community NPVs.*

The variables in equation *Eq*. [5] are:

α^t: Investor discount factor.

C_{1j0}^{plan}: Planning costs.

TC_{1jt}^{indo}: Indonesia-related TCs (taxes, bribes, etc.)

TC_{1jt}^{cdm}: CDM-related TCs.

R_{1jt}^{el}: Electricity revenue.

R_{1jt}^{cdm}: CER revenue.

R_{1jT}^{hor}: The horizon value.

$C_{1jt_{start}}^{build}$: Construction costs.

C_{1jt}^{maint}: Maintenance and variable costs related to plant operation.

C_{1jt}^{land}: Costs of land.

TC_{1jt}^{op}: Operation-related TCs (taxes, bribes, monitoring, etc.)

The variables in equation Eq [6] are:

β^t:	Host country discount factor.
B^{tax}_{2jt}:	Taxes collected from investing firm.
OC^{indo}_{2jt}:	OCs of GOI officials' time.
B^{learn}_{2jt}:	Learning-by doing-effects from the solar PV project.
B^{empl}_{2jt}:	Benefits from reduced unemployment.
B^{invest}_{2jt}:	Benefits from reduced investment need in the power sector.
B^{heal}_{22t}:	Health benefits from replacing polluting diesel generators.
B^{el}_{23t}:	Benefits from earlier electrification of rural villages.
C^{el}_{2jt}:	Costs of electricity (the the end-user payments to the investor).

The variables in equation Eq [7] are:

γ^t:	Annex 1 discount factor.
NPV^{γ}_{1j}:	Equivalent to the investor-NPVs with γ^t replacing α^t as discount factor.
B^{abate}_{3jt}:	Benfits from more cost-effective CO2 abatement (saved abatment costs).

The global community NPV-equation mostly includes variables that are already defined in the equations of the other players. Some of these, however, are collected in the following composite variables:

$$B^{sum}_{4jt} = B^{abate}_{3jt} + B^{learn}_{2jt} + B^{empl}_{2jt} + B^{invest}_{2jt} \tag*{[9]}$$

$$C^{sum}_{4jt} = C^{build}_{1jt_{start}} + C^{maint}_{1jt} + C^{land}_{1jt} + TC^{op}_{1jt} \tag*{[10]}$$

The unique variables in equation Eq [8] are:

λ^t:	Global discount factor.
OC^{cdm}_{41t}:	OCs of CDM-staff's time.
C^{scc}_{4jt}:	Costs of any non-additional CERs handed out, based on the SCC.

3.3. Micro-level incentives

In this section the investment decision is analyzed using decision analysis, allowing for uncertain payoffs. In essence the framework consists of a multi-move sequential game against nature, where the investor acts as an agent choosing outcome on behalf of all the other players. To handle the decision problem as easily as possible, the task of analyzing it is broken up into two sub-problems, namely the commitment problem and the CDM problem. These are tackled in turn below, but first, the basic framework and components of the game is laid out.

3.3.1. The investment problem

3.3.1.1. The basic framework

The investment problem is presented here as seen from the point of view of all the four players studied in the thesis. In this first overview the decision processes of the players viewed to be a black box, and uncertainty is viewed to be non-existent:

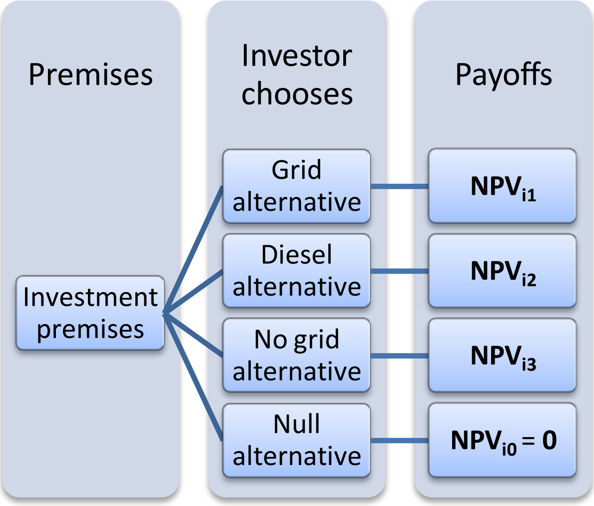

Figure 3.1: The investment decision tree without uncertainty and information costs.

The payoffs are vectors consisting of the payoffs to the different players. $\boldsymbol{NPV_{i1}}$ provides an example:

$$\boldsymbol{NPV_{i1}} = \begin{bmatrix} NPV_{11} \\ NPV_{21} \\ NPV_{31} \\ NPV_{41} \end{bmatrix} \qquad [11]$$

Please note that the setup of the indexes i and j is unchanged from section 3.2.4, see equations [3] and [4]. One further point to note is that the above scenario assumes that information is costless to the investor, as the NPV of choosing the null alternative is simply zero.

The important point in the sequential nature of the decision tree above is that it is the investor that makes the final choice as to which investment alternatives are found viable, based on his or her own NPV calculations, and then makes choices that affect the other levels of analysis, as in any other principal-agent framework.

However, the main point in introducing a risk analysis approach to the CDM is in order to study some of the inherent risks more closely. Figure 3.2 below extends the investment problem to include two types of risks: the risk of CDM rejection and the risk of project failure.

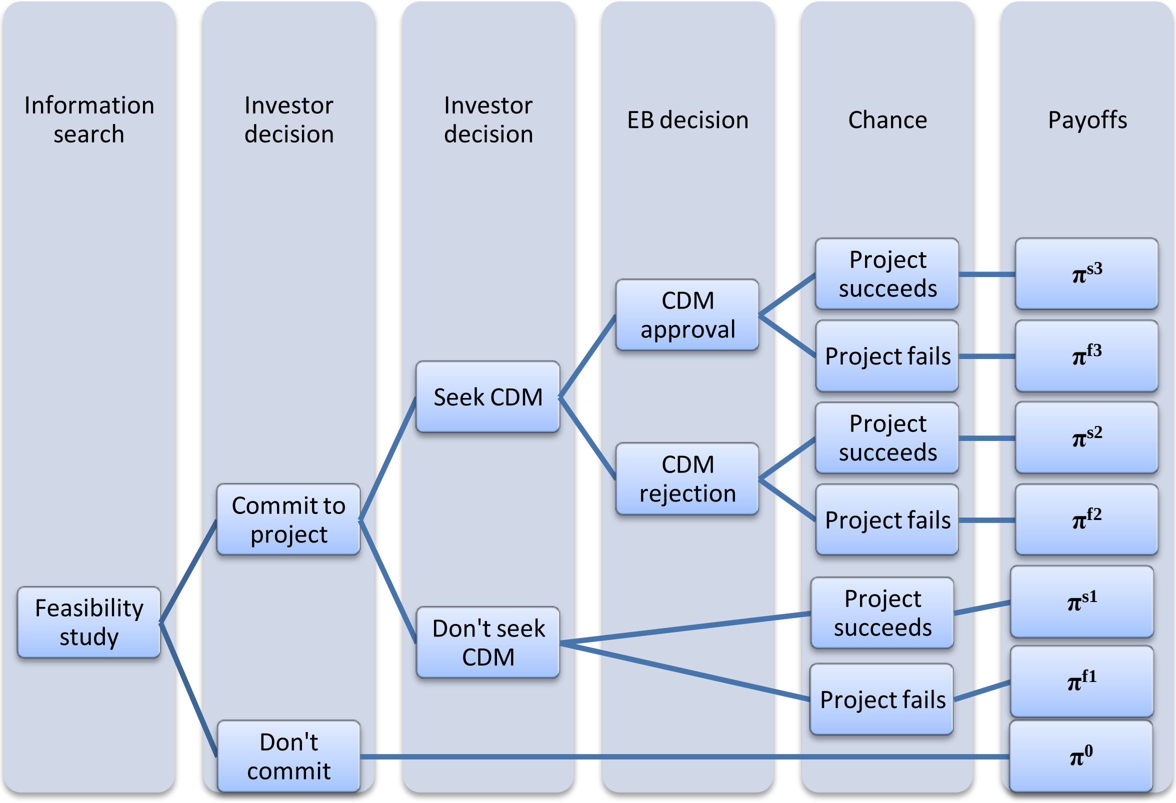

Figure 3.2: The investment decision tree with uncertainty.

A quick word about how the payoffs are presented here is due, to eliminate any confusion with regards to the numbering. The payoffs are structured as vectors. However, because the two layers of uncertainty in the model are somewhat complicating, the need for numbering in the superscript is created. As seen above, the numbering is on the form π^{s_k} and π^{f_k}, where k

is a number signifying which payoff we are dealing with. I must stress that the numbers k takes on are in no way related to choice of player or choice of placement alternative. Each payoff vector, regardless of the numbering in the superscript, is made of four rows, with the payoff to each of the players , and each of the player payoffs are assumed to come from the placement alternative that is the most profitable choice to the investor.

Here is an illustration of the contents of the payoff vector for the k-th success:

$$\boldsymbol{\pi}^{s_k} = \begin{bmatrix} \pi_{1j}^{s_k} \\ \pi_{2j}^{s_k} \\ \pi_{3j}^{s_k} \\ \pi_{4j}^{s_k} \end{bmatrix} \qquad [\ 12]$$

Where the subscripts on each element in the vector refer to players and scenarios in the usual fashion, as defined in equations [3] and [4].

As for the uncertainty in the decision problem, some of the main assumptions are outlined below.

Project failure is taken as meaning to get rejection from the GOI just before the solar PV plant construction starts. This means that only the pre-construction TCs are lost in the case of rejection start of building. Of course, project failure is slightly more complicated in practice: Failure may occur at any given time in project, and the success-failure relationship is more complex than given here, given the many uncertain variables in entering the picture, success-failure is probably more of a continuum than a binary set of choices. But a full treatment of this is outside the scope of the thesis.

Further, a fact that is left out of the model, but probably true to a degree, is that the outcome success/failure can be viewed as *a decision* by the host country community – host country can choose to make the investment process easy or difficult, and can choose whether or not to give out needed permits etc. necessary for start-up. Especially in Indonesia, with high levels of both corruption and decentralization, the process can at best be described as semi-conscious, in the sense that there is little coordinating will, and mostly the narrow self-interest of most of agents acting at their own accord (e.g. local politicians acting in disagreement with national policy). Under these circumstances, and since a through multi-agent principle-agent model of the Indonesian public sector is somewhat outside the scope of this thesis, modeling the success/failure decision as a chance process might very well be the best choice under the circumstances.

The CDM Executive Board is seen here as a single-stop proxy for the entire CDM approval process, although the process in reality is much more complex than a simple one-shot "approved"/"disapproved" stamp from the Executive Board. Further, the EB is assumed to behave non-strategically, in the sense that it will judge CDM-applications (PDDs) only on their fulfillment of the goals of the CDM. The time spent by other CDM-staff leading up to the decision is modeled as a sunk cost, not influencing the likelihood of getting approval from the EB.

The result of the above simplifications is that in the following treatment of the investment problem, the risks are synthesized into two exogenously determined probabilities that are held fixed across all scenarios and all players. The probabilities are denoted p and q, and they refer to the probability of project success and the rate of CDM approval respectively.

p: probability of project success
q: probability of CDM approval

An interpretation of which variables determine p, since it is fixed across scenarios and players is that it is determined by the quality variables of the project developers (competence of employees and investor involved). This would account for the fact that other players take p as exogenously given, but p then becomes endogenous to the decision process of the investor. Under this interpretation of p it is not necessarily unreasonable to assume that $q=p$, as long as the quality of the developers are the same in both the RE and the CDM fields (this is something of a stretch, but not unlikely; as the CDM market would certainly favor such developers).

Finally, when studying this problem, it is assumed that there is one investor player, and that she/he only has funding to proceed with one project. The placement alternative index j is thus in the further decision analysis taken to represent the placement alternative that is most profitable to the investor.

3.3.1.2. New micro-level relevant variables

In order to observe directly the effect that pre-implementation costs and benefits and CDM costs and benefits have on the decision process, these costs are separated out from the NPVs of the players. This is done by introducing the makeshift concept of GNPV, or gross net present value[21], defined as this for each player:

$$\boldsymbol{GNPV_{ij}} = \boldsymbol{NPV_{ij}} + \begin{bmatrix} C_{1j0}^{plan} + \Sigma TC_{1jt}^{indo} \\ -\Sigma B_{2jt}^{tax} + \Sigma OC_{2jt}^{indo} \\ C_{1j0}^{plan} + \Sigma TC_{1jt}^{indo} \\ C_{1j0}^{plan} + \Sigma TC_{1jt}^{indo} + \Sigma OC_{2jt}^{indo} \end{bmatrix} + \begin{bmatrix} \Sigma TC_{1jt}^{cdm} \\ 0 \\ \Sigma TC_{1jt}^{cdm} \\ \Sigma TC_{1jt}^{cdm} + \Sigma OC_{1jt}^{cdm} \end{bmatrix} - \begin{bmatrix} \Sigma R_{1jt}^{cdm} \\ 0 \\ \Sigma B_{1jt}^{cdm} \\ \Sigma B_{1jt}^{abate} - \Sigma C_{4jt}^{scc} \end{bmatrix} \qquad [\,13]$$

As should be clear from the vector equation above, the GNPV simply separates out the effects we want to study from the NPV. The value of this trick should quickly become apparent in the following sections.

3.3.2. The commitment sub-problem without CDM uncertainty

The commitment sub-problem deals with how uncertainty regarding the project outcome affects the investor. It can be stylized like this, once the equilibrium in the CDM sub-problem is found.

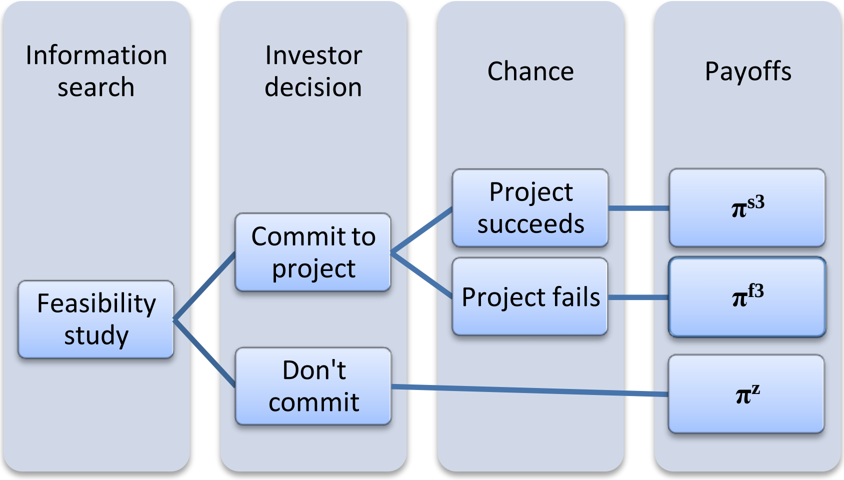

Figure 3.3: The commitment sub-problem without CDM uncertainty.

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[21] The term "gross net present value" is chosen somewhat lightheartedly, as the mild contradiction feels somewhat disarming amidst the large complex of acronyms and symbols in the thesis.

The superscripts s^3 and f^3 refer to the fact that in this version of the commitment sub-problem, it is taken for granted that the investor seeks CDM and gets it approved. See Figure 3.2 above for the full context.

The payoffs under success are:

$$\boldsymbol{\pi}^{s_3} = \begin{bmatrix} GNPV_{1j} - C_{1j0}^{plan} - \Sigma TC_{1jt}^{cdm} - \Sigma TC_{1jt}^{indo} + \Sigma R_{1jt}^{cdm} \\ GNPV_{2j} + \Sigma B_{2jt}^{tax} - \Sigma OC_{2jt}^{indo} \\ GNPV_{3j} - C_{1j0}^{plan} - \Sigma TC_{1jt}^{cdm} - \Sigma TC_{1jt}^{indo} + \Sigma B_{3jt}^{abate} \\ GNPV_{4j} - C_{1j0}^{plan} - \Sigma TC_{1jt}^{cdm} - \Sigma TC_{1jt}^{indo} - \Sigma OC_{2jt}^{indo} - \Sigma OC_{4jt}^{cdm} + \Sigma B_{3jt}^{abate} - \Sigma C_{4jt}^{scc} \end{bmatrix}$$

[14]

The summation signs refer to the discounted stream of benefits or costs summed over the appropriate time period[22]. The benefits and costs are taken from the NPV equations *Eq.* [5] to *Eq* [8].

Following the same framework, the payoffs in the case of project failure are:

$$\boldsymbol{\pi}^{f_3} = \begin{bmatrix} -C_{1j0}^{plan} - \Sigma TC_{1jt}^{cdm} - \Sigma TC_{1jt}^{indo} \\ \Sigma B_{2jt}^{tax} - \Sigma OC_{2jt}^{indo} \\ -C_{1j0}^{plan} - \Sigma TC_{1jt}^{cdm} - \Sigma TC_{1jt}^{indo} \\ -C_{1j0}^{plan} - \Sigma TC_{1jt}^{cdm} - \Sigma TC_{1jt}^{indo} - \Sigma OC_{2jt}^{indo} - \Sigma OC_{4jt}^{cdm} \end{bmatrix}$$

[15]

And lastly, the payoffs in the case of non-commitment are:

$$\boldsymbol{\pi}^{z} = \begin{bmatrix} -C_{1j0}^{plan} \\ 0 \\ -C_{1j0}^{plan} \\ -C_{1j0}^{plan} \end{bmatrix}$$

[16]

The success rate p of projects and use of the simple probability theory[23] gives the following expected profits given commitment:

---

[22] See the NPV equations *Eq.* [5] to *Eq* [8] for details on the different time frames of summation.

$$\boldsymbol{E}(\boldsymbol{\pi}|\mathbf{comc}) = p\boldsymbol{\pi}^{s_3} + (1-p)\boldsymbol{\pi}^{f_3} \quad [17]$$

Where “comc” indicates “commitment with certain CDM payments”.

Solving this equation system for all players given the payoffs outlined above gives the following vector of expected payoffs:

$$\boldsymbol{E}(\boldsymbol{\pi}|\mathbf{comc}) = \begin{bmatrix} p\,(GNPV_{1j} + \Sigma R_{1jt}^{cdm}) - C_{1j0}^{plan} - \Sigma TC_{1jt}^{cdm} - \Sigma TC_{1jt}^{indo} \\ p\,GNPV_{2j} + \Sigma B_{2jt}^{tax} - \Sigma OC_{2jt}^{indo} \\ p\,(GNPV_{3j} + \Sigma B_{3jt}^{abate}) - C_{1j0}^{plan} - \Sigma TC_{1jt}^{cdm} - \Sigma TC_{1jt}^{indo} \\ p\,(GNPV_{4j} + \Sigma B_{3jt}^{abate} - \Sigma C_{4jt}^{scc}) - C_{1j0}^{plan} - \Sigma TC_{1jt}^{cdm} - \Sigma TC_{1jt}^{indo} - \Sigma OC_{2jt}^{indo} - \Sigma OC_{4jt}^{cdm} \end{bmatrix} \quad [18]$$

The theoretical insight gleaned from these relationships is that the costs of implementation are much more significant in a world of uncertainty than they are in a pure NPV-model setting. The other costs and benefits are subject to an additional round of “discounting” through p due to the uncertainties regarding project success.

p is thus an important parameter, and although it will generally be difficult to quantify p, due to the lack of a credible dataset on the project success rate[24], this does not mean that we cannot say something meaningful about p. We can, since all the other elements in the equation can be assumed to be known in the quantification in this thesis, compute threshold values for p, that is values of p for which the player’s are indifferent to committing to the project.

Assuming risk neutrality[25], the players will prefer to commit to the project when:

$$\boldsymbol{E}(\boldsymbol{\pi}_1|\mathbf{comc}) \geq \boldsymbol{\pi}^{z} \quad [19]$$

---

[23] The method is simple, and as far as market costs and benefits are concerned it is also universally accepted. When non-market effects are present, we enter the slippery slope of utilities, and have to assume cardinal utilities in order to use the method. The validity of cardinal utility is contested at best, but the simplification gains are worthwhile, as long as the results are treated with care.

[24] This is true both for RE projects in general (REF) and for Indonesia as a host country for RE projects in specific (REF).

[25] The same assumption is made for all the players in all settings in the rest of the thesis, unless otherwise noted.

Conversely, they are indifferent when:

$$\boldsymbol{E}(\boldsymbol{\pi}_1|\mathbf{comc}) - \boldsymbol{\pi}^{\boldsymbol{z}} = 0 \tag*{[20]}$$

Using the investor as an example, in order to handle a smaller and bit more tractable equation system we get:

$$p\ (GNPV_{1j} + \Sigma R_{1jt}^{cdm}) - C_{1j0}^{plan} - \Sigma TC_{1jt}^{cdm} - \Sigma TC_{1jt}^{indo} - \left(-C_{1j0}^{plan}\right) = 0 \tag*{[21]}$$

By rearranging we obtain a threshold value for p, denoted as $\overline{p_1^{com}}$, with the index indicating that the player in question is the investor:

$$\overline{p_1^{comc}} = \frac{\Sigma TC_{1jt}^{cdm} + \Sigma TC_{1jt}^{indo}}{GNPV_{1j} + \Sigma R_{1jt}^{cdm}} \tag*{[22]}$$

The right hand side of the above equation can be considered as known given the data collected in this thesis. A potential investor can then use his or her subjective probabilities in order to determine whether to commit to the project or not given the information she or he has got. The rule of thumb can be given as follows, where $\widehat{p_1}$ denotes the investor's subjective estimate of p[26]:

$$\widehat{p_1} \geq \overline{p_1^{comc}} \quad \Leftrightarrow \quad \text{Commit to the project.} \tag*{[23]}$$

Or, conversely:

$$\widehat{p_1} < \overline{p_1^{comc}} \quad \Leftrightarrow \quad \text{Don't commit to the project.} \tag*{[24]}$$

$\widehat{p_1}$ will in many ways symbolize the investor's faith in the investment project, and it will as such be contingent upon all criteria that contribute to the certainty (or uncertainty) of

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[26] Please note that the decision rules in equations [23] and [24] both are valid only under the assumption of positive GNPVs. The direction of the inequalities are reversed under negative GNPVs.

success[27]. The consequences of this line of thinking are explored further in the discussion section.

At first glance it might seem that computing a decision rule is an exercise worthwhile only when done for the only player which actually makes any choices in the investment problem, namely the investor. But decision rules for the other players represent an interesting counterfactual, hinting at what sort of subjective probabilities are needed on their part in order to find be content with the choice made by the investor as an agent acting on their behalf.

Through using the same procedure as for the investor, including the assumption of risk averseness, similar rules can be obtained for the other players. All the decision rules are summarized Table 3.2 below.

Table 3.2: Collected threshold relationships for commitment without CDM uncertainty.

Player	**Threshold value**
Investor	$\overline{p_1^{comc}} = \frac{\Sigma TC_{1jt}^{cdm} + \Sigma TC_{1jt}^{indo}}{GNPV_{1j} + \Sigma R_{1jt}^{cdm}}$
Host	$\overline{p_2^{comc}} = \frac{\Sigma OC_{2jt}^{indo} - \Sigma B_{2jt}^{tax}}{GNPV_{2j}}$
Annex 1	$\overline{p_3^{comc}} = \frac{\Sigma TC_{1jt}^{cdm} + \Sigma TC_{1jt}^{indo}}{GNPV_{3j} + \Sigma B_{3jt}^{abate}}$
Global community	$\overline{p_4^{comc}} = \frac{\Sigma TC_{1jt}^{cdm} + \Sigma TC_{1jt}^{indo} + \Sigma OC_{2jt}^{indo} + \Sigma OC_{4jt}^{cdm}}{GNPV_{4j} + \Sigma B_{3jt}^{abate} - \Sigma C_{4jt}^{scc}}$

Note that the results above are easily transferred to a no-CDM scenario simply through removing the CDM-related costs and benefits in the equations in Table 3.2.

The implications of these decision rules are investigated further in the discussion section. Two factors are worth noting already here, however: the double burden of transaction costs on the global community, and the rather deviant decision rule of the host country.

---

[27] The lack of any superscript on $\widehat{p_1}$ is intentional, as this subjective probability will not change across the different subgames studied.

A general remark is due regarding the host country threshold value relationship: the right hand side of equality can be negative, implying an "auto-yes" function (as long as GNPV is above zero), as even subjective probabilities can never be below zero. This is especially interesting when viewed together with the fact that for the other players, when GNPV is negative, it constitutes an "auto-no", as *p* then is required to be below some negative number to warrant project commitment. This is not true for the host country: If both the quotient and the divisor are negative, then *p* will be required to be smaller than some non-zero number. *A priori*, this might well be feasible.

3.3.3. The CDM sub-problem

The CDM sub-problem, with uncertainty regarding both CDM approval and project success modeled in, is stylized in Figure 3.4 below.

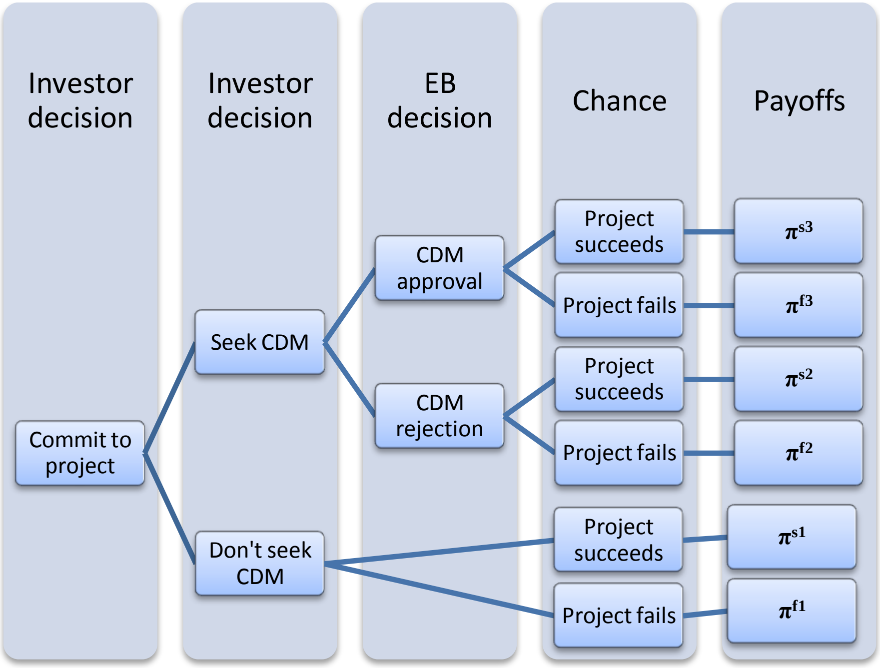

Figure 3.4: The CDM decision tree.

The superscripts on the payoffs are, as illustrated in equation [12], not to be confused with the already established system governing the subscripts in this thesis.

The payoffs in the CDM sub-problem are given in detail in Table 3.3 on the next page.

Table 3.3: Payoffs in the CDM sub-problem.

Seek CDM				**Don’t seek CDM**	
CDM approval		***CDM rejection***			
Project succeeds	*Project fails*	*Project succeeds*	*Project fails*	*Project succeeds*	*Project fails*
$\boldsymbol{\pi}^{s_3} = \boldsymbol{\pi}^{s_2} + \begin{bmatrix} \Sigma R_{1jt}^{cdm} \\ 0 \\ \Sigma B_{1jt}^{cdm} \\ \Sigma B_{1jt}^{abate} - \Sigma C_{4jt}^{scc} \end{bmatrix}$	$\boldsymbol{\pi}^{f_3} = \boldsymbol{\pi}^{f_2}$	$\boldsymbol{\pi}^{s_2} = \boldsymbol{\pi}^{f_2} + \begin{bmatrix} GNPV_{1j} \\ GNPV_{2j} \\ GNPV_{3j} \\ GNPV_{4j} \end{bmatrix}$	$\boldsymbol{\pi}^{f_2} = \boldsymbol{\pi}^{f_1} - \begin{bmatrix} \Sigma TC_{1jt}^{cdm} \\ 0 \\ \Sigma TC_{1jt}^{cdm} \\ \Sigma TC_{1jt}^{cdm} + \Sigma OC_{1jt}^{cdm} \end{bmatrix}$	$\boldsymbol{\pi}^{s_1} = \boldsymbol{\pi}^{f_1} + \begin{bmatrix} GNPV_{1j} \\ GNPV_{2j} \\ GNPV_{3j} \\ GNPV_{4j} \end{bmatrix}$	$\boldsymbol{\pi}^{f_1} = \begin{bmatrix} -C_{1j0}^{plan} - \Sigma TC_{1jt}^{indo} \\ \Sigma B_{2jt}^{tax} - \Sigma OC_{2jt}^{indo} \\ -C_{1j0}^{plan} - \Sigma TC_{1jt}^{indo} \\ -C_{1j0}^{plan} - \Sigma TC_{1jt}^{indo} - \Sigma OC_{2jt}^{indo} \end{bmatrix}$

The OCs to the GOI when treating a CDM RE project are assumed to be identical to the OCs to the GOI when treating a regular RE project, thus, no additional OCs to the host are modeled into the payoffs under the seek CDM option. Given the extent of the bureaucracy in GOI in general, contrasted with the rather small role of the DNA in the CDM process, this seems as a reasonable assumption at least for Indonesia as a host country.

Just as for the commitment sub-problem, the reader is referred to the NPV equations, *Eq*. [5] to *Eq* [8], for details on benefits and costs used here, and their appropriate horizon of summation.

The ranking of failure payoffs is as follows:

$$\boldsymbol{\pi}^{f_1} \geq \boldsymbol{\pi}^{f_2} = \boldsymbol{\pi}^{f_3} \qquad [\ 25]$$

And the ranking of the success payoffs is:

$$\boldsymbol{\pi}^{s_3} \geq \boldsymbol{\pi}^{s_1} \geq \boldsymbol{\pi}^{s_2} \qquad [\ 26]$$

The vector notation hides one fact that can be seen in Table 3.3: if it were not for the host payoffs, the inequalities in equation [25] and [26] above would all be strict.

The results are somewhat different if we imagine a world without TCs (and their mirror image, the OCs of administrator time in the GOI and the CDM staff), taxes and planning costs[28] the investment decision becomes much more clear cut:

$$\boldsymbol{\pi}^{f_1} = \boldsymbol{\pi}^{f_2} = \boldsymbol{\pi}^{f_3} = \mathbf{0} \qquad [\ 27]$$

$$\boldsymbol{\pi}^{s_1} = \boldsymbol{\pi}^{s_2} \leq \boldsymbol{\pi}^{s_3} \qquad [\ 28]$$

In plan words: with nothing to lose from trying and failing, the most attractive option of course becomes trying (as long as the GNVP is positive, of course).

In the following, expected payoffs are derived in the Two expected payoffs are of special interest in the CDM sub-problem, namely the expected payoffs given application for the CDM and the expected payoff given commitment when uncertainty regarding CDM outcome is taken into account. These two expected payoffs and their respective decision rules are derived below, in section 3.3.3.1 and section 3.3.3.2 respectively.

---

[28] It might sound far-fetched having seen the sources of TCs, but in reality TCs are often ignored in analyses.

3.3.3.1: Decision rules regarding CDM application

Given that the players commit, or more, precisely, given that the investor commits, the goal will be to maximize the expected payoff given commitment, $\boldsymbol{E}(\boldsymbol{\pi}|\mathbf{com})$. However, the investor is the player who chooses, and thus the function becomes:

$$\boldsymbol{E}(\boldsymbol{\pi}|\mathrm{com}) = \max_{\pi_{1j}} \begin{Bmatrix} \boldsymbol{E}(\boldsymbol{\pi}|\mathbf{CDM\ appl}) \\ \boldsymbol{E}(\boldsymbol{\pi}|\mathbf{no\ CDM}) \end{Bmatrix} \qquad [\ 29]$$

Where π_{1j} is the payoff to the investor.

In the following, the fact that it is only the investor that chooses will be ignored, in order to produce decision rules for all players. Allowing for this, the players will all prefer the investor to apply for CDM when:

$$\boldsymbol{E}(\boldsymbol{\pi}|\mathbf{CDM\ appl}) \geq \boldsymbol{E}(\boldsymbol{\pi}|\mathbf{no\ CDM}) \qquad [\ 30]$$

Similarly, they are all indifferent when:

$$\boldsymbol{E}(\boldsymbol{\pi}|\mathbf{CDM\ appl}) - \boldsymbol{E}(\boldsymbol{\pi}|\mathbf{no\ CDM}) = \mathbf{0} \qquad [\ 31]$$

The interesting variable to elicit from equation [31] will be a probability threshold for when the CDM gamble is preferable over the “sure thing” of not applying for CDM[29]. This is done below.

The vectors in equation [31] are in turn defined by applying the respective payoffs from Table 3.3 and application of simple probability theory, as in the commitment problem. The difference here is the number of layers involved. Tackling the expected payoffs from applying CDM first, this vector is made up of the following components:

$$\boldsymbol{E}(\boldsymbol{\pi}|\mathbf{CDM\ appl}) = q\ \boldsymbol{E}(\boldsymbol{\pi}|\mathbf{CDM\ appr}) + (1-q)\boldsymbol{E}(\boldsymbol{\pi}|\mathbf{CDM\ reject}) \qquad [\ 32]$$

---

[29] “Sure thing” in the sense that it is less risky than applying for CDM, as long as the CDM outcome is not 100% certain and the CDM-related TCs are greater than zero.

Where the components in turn are made up of the following:

$$\boldsymbol{E}(\boldsymbol{\pi}|\textbf{CDM appr}) = p\ \boldsymbol{\pi}^{s_3} + (1-p)\ \boldsymbol{\pi}^{f_3} \tag*{[33]}$$

And:

$$\boldsymbol{E}(\boldsymbol{\pi}|\textbf{CDM reject}) = p\ \boldsymbol{\pi}^{s_2} + (1-p)\boldsymbol{\pi}^{f_2} \tag*{[34]}$$

The above relationships combined with the individual payoffs presented in Table 3.3 gives the following expected payoffs given CDM application:

$$\boldsymbol{E}(\boldsymbol{\pi}|\textbf{CDM appl}) = \ q\ p\begin{bmatrix} \Sigma R_{1jt}^{cdm} \\ 0 \\ \Sigma B_{1jt}^{abate} \\ \Sigma B_{1jt}^{abate} - \Sigma C_{4jt}^{scc} \end{bmatrix} + p\begin{bmatrix} GNPV_{1j} \\ GNPV_{2j} \\ GNPV_{3j} \\ GNPV_{4j} \end{bmatrix} + \boldsymbol{\pi}^{f_2} \tag*{[35]}$$

The expected payoffs from not applying CDM on the other hand are given as:

$$\boldsymbol{E}(\boldsymbol{\pi}|\textbf{no CDM}) = p\ \boldsymbol{\pi}^{s_1} + (1-p)\boldsymbol{\pi}^{f_1} \tag*{[36]}$$

Inserting the appropriate payoffs from table Q and rearranging gives:

$$\boldsymbol{E}(\boldsymbol{\pi}|\textbf{no CDM}) = p\begin{bmatrix} GNPV_{1j} \\ GNPV_{2j} \\ GNPV_{3j} \\ GNPV_{4j} \end{bmatrix} + \boldsymbol{\pi}^{f_1} \tag*{[37]}$$

By combining equations [31] to [37] above, the knowledge of the components in the payoffs as seen in Table 3.3, and some algebra, the following threshold relationship for indifference is obtained:

$$q\ p\begin{bmatrix} \Sigma R_{1jt}^{cdm} \\ 0 \\ \Sigma B_{1jt}^{abate} \\ \Sigma B_{1jt}^{abate} - \Sigma C_{4jt}^{scc} \end{bmatrix} - \begin{bmatrix} \Sigma TC_{1jt}^{cdm} \\ 0 \\ \Sigma TC_{1jt}^{cdm} \\ \Sigma TC_{1jt}^{cdm} + \Sigma OC_{1jt}^{cdm} \end{bmatrix} = \mathbf{0} \tag*{[38]}$$

Just as in the commitment problem, the relationship above highlights the increased importance of transaction costs under uncertainty. The fact comes even more strongly across here, as the CDM-related stream of revenues is doubly uncertain and therefore doubly "discounted".

The joint presence of q and p in the same equation, presents something of a problem, however. The other elements in the equation are assumed to be known, but, as determined in section 3.3.2, p is unlikely to be known. It can be argued that q, the probability of CDM approval, is probably just as hard to quantify as p. Hallre (2010) tries to estimate the probability of CDM approval for small-scale projects by estimating a probit-model with validation as the dependent variable. She controls for a variety of different independent variables, but concludes that the model has both low explanatory power and endogeneity problems[30] (Hallre 2010, p 60). This illustrates the problems inherent in estimating q. A full treatise is beyond the scope of this thesis.

If both q and p are beyond estimation, the computation of a decision rule for when to apply CDM with only a single unknown parameter is impossible. Unless one possesses knowledge of or imposes some additional assumption about the relationship between q and p. I do not possess knowledge about a definite relationship, so I intend instead to impose one. As discussed in section 3.3.1.1 it is not necessarily unreasonable to assume the following:

$$q = p \qquad [39]$$

This imposed assumption reduces the threshold relationship to:

$$p^2 \begin{bmatrix} \Sigma R_{1jt}^{cdm} \\ 0 \\ \Sigma B_{1jt}^{cdm} \\ \Sigma B_{1jt}^{abate} - \Sigma C_{4jt}^{scc} \end{bmatrix} - \begin{bmatrix} \Sigma TC_{1jt}^{cdm} \\ 0 \\ \Sigma TC_{1jt}^{cdm} \\ \Sigma TC_{1jt}^{cdm} + \Sigma OC_{1jt}^{cdm} \end{bmatrix} = \mathbf{0} \qquad [40]$$

---

[30] Hallre (2010) concludes that the endogeneity problems are most likely caused by omitted variables and unobserved effects.

By applying some algebra and ruling out the solutions that entail negative values for p, we get the decision rules reproduced in Table 3.4 below.

Table 3.4: Threshold values for CDM application.

Player	**Threshold values**
Investor	$\overline{p_1^{cdm}} = \sqrt{\frac{\Sigma TC_{1jt}^{cdm}}{\Sigma R_{1jt}^{cdm}}}$
Host	Indifferent.
Annex 1	$\overline{p_3^{cdm}} = \sqrt{\frac{\Sigma TC_{1jt}^{cdm}}{\Sigma B_{1jt}^{abate}}}$
Global community	$\overline{p_4^{cdm}} = \sqrt{\frac{\Sigma TC_{1jt}^{cdm} + \Sigma OC_{1jt}^{cdm}}{\Sigma B_{1jt}^{abate} - \Sigma C_{4jt}^{scc}}}$

Where $\overline{p_j^{cdm}}$ denotes the threshold value of player j, and the decision rule is:

$$\overline{p_j^{cdm}} \geq \widehat{p_j} \quad \Rightarrow \quad \text{Apply for CDM.} \qquad [41]$$

Here, the host country is placed on the sideline as indifferent, as by design, the host country has no unique CDM-related costs or benefits.

There are some interesting relationships to be read from the above table. The discount rate used for the Annex 1 country is guaranteed to be lower when compared to the investor discount rate, and this increases ΣB_{1jt}^{abate} for the Annex 1 country compared to the value of ΣR_{1jt}^{cdm} to the investor. This effect will also increase the size of ΣTC_{1jt}^{cdm} for the Annex 1 country, but as the time horizon used here is by all likelihood much shorter than the time horizon used for the benefits, that difference will be much smaller for the TCs. If we further assume that $B_{1jt}^{abate} \geq R_{1jt}^{cdm}$ in the first place, something which seems reasonable in order for the Annex 1 country to be motivated to partake in the CDM in the first place, then the following relationship is implied:

$$\overline{p_3^{cdm}} < \overline{p_1^{cdm}} \qquad [42]$$

Further, as long as ΣOC_{1jt}^{cdm} and ΣC_{4jt}^{scc} are high enough to offset the increase in ΣB_{1jt}^{abate} that occurs if the global community discount rate is lower than the discount rate for the Annex 1 country[31], then:

$$\overline{p_4^{cdm}} > \overline{p_3^{cdm}} \qquad [\ 43]$$

Combining equation [42] and [43] sums up nicely:

$$\overline{p_4^{cdm}} > \overline{p_3^{cdm}} < \overline{p_1^{cdm}} \qquad [\ 44]$$

Indicating *a priori* that the threshold value for the Annex 1 countries will be the lowest of the three.

The relationship between $\overline{p_4^{cdm}}$ and $\overline{p_1^{cdm}}$, however, is still somewhat unclear *a priori*, as illustrated below:

$$\overline{p_4^{cdm}} \lesseqgtr \overline{p_1^{cdm}}\ ? \qquad [\ 45]$$

All the threshold values are quantified and presented in the results section. The discussion section offers further perspectives on the relationship between the threshold values, based on the combined insights from the quantification and from the *a priori* considerations derived here.

3.3.3.2. Decision rules in the commitment problem with CDM uncertainty

Having determined $\boldsymbol{E}(\boldsymbol{\pi}|\textbf{CDM appl})$ and $\boldsymbol{E}(\boldsymbol{\pi}|\textbf{no CDM})$, the next step towards completing the investment problem is to determine a set of decision rules for the commitment problem with both CDM and outcome uncertainty.

---

[31] This is a likely scenario, as the difference in discount rate between the two players are likely to be small if even existing, as Annex 1 countries in general seem to employ good discount practices.

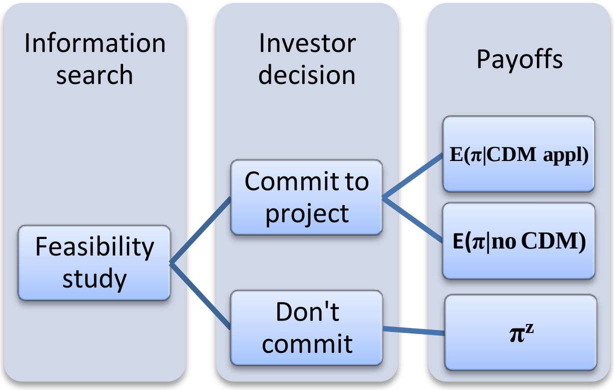

Figure 3.5: The commitment decision tree with uncertain CDM outcome.

As indicated in Figure 3.5 above, the expected outcome of committing to the project depending on investor choice, and the investor will choose whichever is the largest of $\boldsymbol{E}(\boldsymbol{\pi}|\text{CDM appl})$ and $\boldsymbol{E}(\boldsymbol{\pi}|\text{no CDM})$, as expressed in equation [29]. These expected payoff expressions, as well as the threshold relationship for indifference, are all derived in section 3.3.3.1.

As there is no way to determine *a priori* which is larger of $\boldsymbol{E}(\boldsymbol{\pi}|\text{CDM appl})$ and $\boldsymbol{E}(\boldsymbol{\pi}|\text{no CDM})$, we have to introduce a two-headed set of decision rules:

$$\boldsymbol{E}(\boldsymbol{\pi}|\text{CDM appl}) \geq \boldsymbol{\pi}^{\boldsymbol{z}} \quad \cup \quad \boldsymbol{E}(\boldsymbol{\pi}|\text{no CDM}) \geq \boldsymbol{\pi}^{\boldsymbol{z}} \quad \Rightarrow \quad \text{Commit to project.}$$ [46]

Tackling the first part of the decision rule set first, the indifference condition is:

$$\boldsymbol{E}(\boldsymbol{\pi}|\text{CDM appl}) - \boldsymbol{\pi}^{\boldsymbol{z}} = \boldsymbol{0}$$ [47]

Drawing upon the expected payoff derived in section 3.3.3.1 and the definition of $\boldsymbol{\pi}^{\boldsymbol{z}}$ we get the following threshold value relationship:

$$q\,p\begin{bmatrix} \Sigma R_{1jt}^{cdm} \\ 0 \\ \Sigma B_{1jt}^{abate} \\ \Sigma B_{1jt}^{abate} - \Sigma C_{4jt}^{scc} \end{bmatrix} + p\begin{bmatrix} GNPV_{1j} \\ GNPV_{2j} \\ GNPV_{3j} \\ GNPV_{4j} \end{bmatrix} + \boldsymbol{\pi}^{\boldsymbol{f}_2} + \begin{bmatrix} C_{1j0}^{plan} \\ 0 \\ C_{1j0}^{plan} \\ C_{1j0}^{plan} \end{bmatrix} = \boldsymbol{0}$$ [48]

The last vector in the equation above indicates that the planning costs are from $\boldsymbol{\pi}^{\boldsymbol{f_2}}$, as they are irrelevant to the decision, just as in the version of commitment problem with certain CDM approval.

Substituting in $q = p$, and solving the resulting equation system as set of quadratic equations gives the first half of the decision rules given in Table 3.5 below.

Turning to the second part of the decision rule set and applying the same method, we get the following threshold value relationship:

$$p\begin{bmatrix} GNPV_{1j} \\ GNPV_{2j} \\ GNPV_{3j} \\ GNPV_{4j} \end{bmatrix} + \boldsymbol{\pi}^{\boldsymbol{f_1}} + \begin{bmatrix} C_{1j0}^{plan} \\ 0 \\ C_{1j0}^{plan} \\ C_{1j0}^{plan} \end{bmatrix} = \mathbf{0} \qquad [49]$$

This system of equation is easily solved, and the results are presented as the second half of the threshold value equations given in Table 3.5 below.

Table 3.5: Threshold values in the commitment problem with uncertain CDM outcome.

Player	**Commit to the project if...**
Investor	$\overline{p_1^{com,A}} = \frac{-GNPV_{1j} + \sqrt{(GNPV_{1j})^2 + 4\,\Sigma R_{1jt}^{cdm}\left(\Sigma TC_{1jt}^{cdm} + \Sigma TC_{1jt}^{indo}\right)}}{2\,\Sigma R_{1jt}^{cdm}}$ $\cup$ $\overline{p_1^{com,B}} = \frac{\Sigma TC_{1jt}^{indo}}{GNPV_{1j}}$
Host[32]	$\overline{p_2^{com,A}} = \overline{p_2^{com,B}} = \frac{\Sigma OC_{2jt}^{indo} - \Sigma B_{2jt}^{tax}}{GNPV_{2j}}$
Annex 1	$\overline{p_3^{com,A}} = \frac{-GNPV_{3j} + \sqrt{(GNPV_{3j})^2 + 4\,\Sigma B_{3jt}^{abate}\left(\Sigma TC_{1jt}^{cdm} + \Sigma TC_{1jt}^{indo}\right)}}{2\,\Sigma B_{3jt}^{abate}}$ $\cup$

---

[32] The payoff to the host is identical with and without CDM, and hence the two parts of the decision rule are also identical.

	$\overline{p_3^{com,B}} = \frac{\Sigma TC_{1jt}^{indo}}{GNPV_{3j}}$
Global	$\overline{p_4^{com,A}} = \frac{-GNPV_{3j} \pm \sqrt{(GNPV_{3j})^2 + 4\left(\Sigma B_{3jt}^{abate} - \Sigma C_{4jt}^{scc}\right)\left(\Sigma TC_{1jt}^{cdm} + \Sigma TC_{1jt}^{indo} + \Sigma OC_{2jt}^{indo} + \Sigma OC_{4jt}^{cdm}\right)}}{2\left(\Sigma B_{3jt}^{abate} - \Sigma C_{4jt}^{scc}\right)}$ $\cup$ $\overline{p_4^{com,B}} = \frac{\Sigma TC_{1jt}^{indo} + \Sigma OC_{2jt}^{indo}}{GNPV_{4j}}$

The commitment rule with uncertainties for player i is:

$$\hat{p}_i \geq \overline{p_i^{com,A}} \quad \cup \quad \hat{p}_j \geq \overline{p_i^{com,B}} \quad \Rightarrow \quad \text{Commit to the project.} \qquad [50]$$

3.3.4 The CDM as a game

While the derivation of decision rules deals with non-strategic behavior in the face of uncertainty, the CDM can also be viewed as a game.

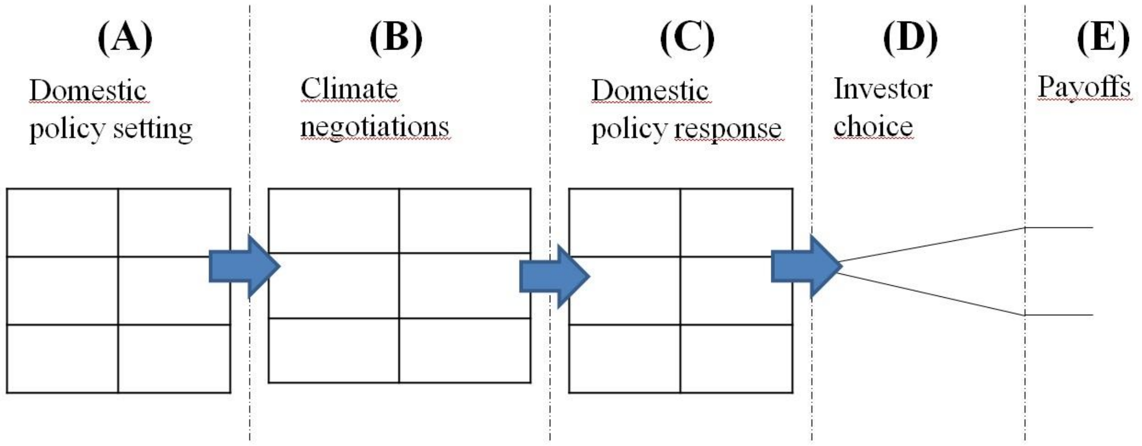

Figure 3.6: The overall CDM game.

An interpretation of the CDM game is sketched out in Figure 3.6. The overall game can be viewed as a sequential game structure, consisting of steps (A) to (D), with payoffs in step (E). The players in the game are thought to be all the countries that are part of the UNFCCC, but in the following the game will be treated as a two player game with a host country and an Annex 1 country as its players. The motivation of the players can be viewed either as maximizing the welfare of the nation, or, from a more cynical view point, to ensure popularity and reelection of the sitting candidates – both ways work.

The tables in steps (A), (B) and (C) are visual aids signifying that the three steps are thought to be three separate simultaneous games, played in sequence. The simultaneous games are representing the overall climate negotiations and the setting of domestic policies – before and after the climate negotiations, respectively. In reality, the climate negotiations are of course much more complex than a simple one shot simultaneous game. But as the negotiations are not the object of study in this thesis, the simplification seems unproblematic for the moment. The main point of the setup is simply to indicate the presence of strategic considerations and linkage of the international and the national aspects of climate policy in the overall complex of the international CDM-related game.

The linkage between the different steps are simply modeled as a sequential chain of events in Figure 3.6. The outcomes in the domestic policy setting game in step (A) influence the available strategies and payoffs in the climate negotiation game in step (B). And in turn, the outcomes in the climate negotiation game spark a simultaneous game where countries change domestic policies in response to the outcome of the climate negotiation, in order to fulfill their obligations. This clear linear and sequential setup is of course another simplification. In reality, it is not unlikely that the different games that are ordered into tidy steps here overlap in time and to a larger extent evolve side by side, influencing each other to a greater extent than the simple causal relationship used in Figure 3.6. However, the simplification serves the purpose.

As for the question of whether the different steps can be considered as games an example, the literature section should answer this pretty well as far as the climate negotiations go. Considering the rest of the steps, the game framework is appropriate in step (A) and (C) as well, as domestic policy in one country will affect domestic policy payoffs in other countries, through trade, the solution to global externality problems like GHG emissions, etc., and each country is thought to be interested in maximizing their own profit, at the expense of other players if necessary.

Step (D) is in essence the decision and selection process of the investor, as outlined in previous subsections of section 3.3. In Figure 3.6 the selection process is represented as a choice between four options (two in the figure, for simplicity). As for the effect of uncertainty, as has been the chief concern of in the thesis so far, the game framework above is appropriate for both certain and uncertain payoffs. Only the payoffs themselves change (from certain payoffs to expected payoffs, smaller than their certain counterparts).

The game setup can be further modified if one allows the host country the possibility of a strategic response to the investor decision regarding project alternative. The setup then becomes:

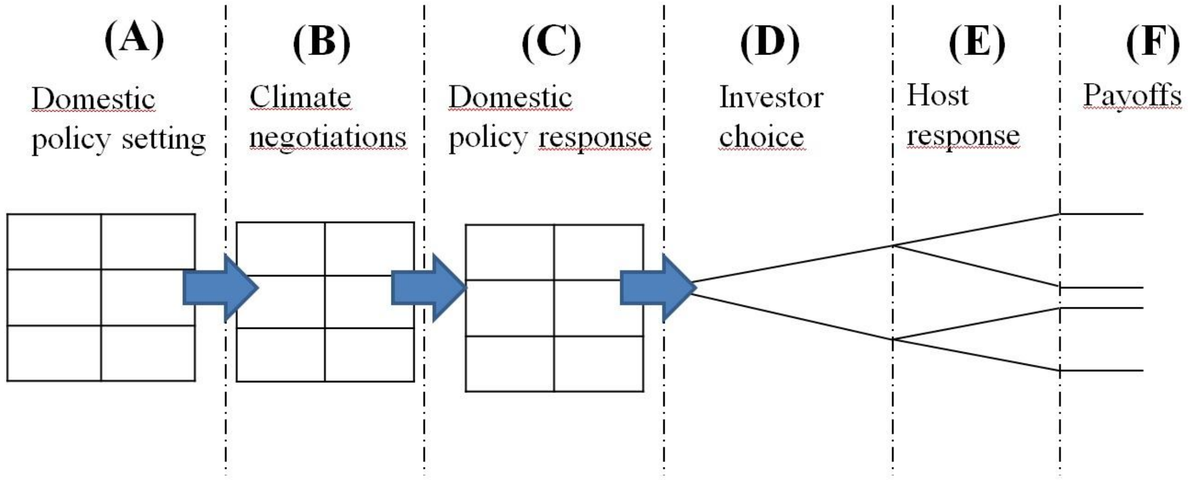

Figure 3.7: The overall CDM game with added host strategic response.

Strategically reacting to single-investor is problematic in the sense that it decreases the predictability of the investment climate, something that might have a negative effect how attractive the investor views the host country economy as a whole. But if such behavior gives short term gains and institutions are not strong enough to control the self-interest of the host country stakeholders, such strategic reactions might very well occur.

3.4. Sensitivity analysis methods

Two methods of sensitivity analysis are employed in this thesis: partial sensitivity analysis, and scenario analysis. The reasons for performing partial sensitivity analysis are twofold in this thesis: One is to get a feel for where any uncertainties in the estimated parameters might cause the most radical changes, and the second is to determine which parameters might be most fruitful to alter in order to change the behavior of the players. Regarding the latter reason, it is the parameters of the agent and the host country which are most interesting. The investor is the acting agent and is therefore an obvious candidate for study. As for the host country, it is most relevant to study as it appears that the host country has the incentive structure that is most divergent from the global community and Annex 1 preferences.

In the following sections, first the foundations of the partial sensitivity analysis used are laid out, and then, the detailed scenarios used in the scenario analysis are described.

3.4.1. Partial sensitivity analysis

The partial sensitivity analysis looks at *ceteris paribus* effects on the NPV, namely the point elasticity of the NPV with respect to different key parameters, and the critical values of key parameters.

The elasticity is calculated with basis in the standard definition of point elasticity (see e.g.Varian 1992, p 13):

$$\varepsilon_{y\ wrt\ x} = \frac{dy}{dx} \cdot \frac{x}{y} \qquad [\ 51]$$

However, the lack of a defined functional form in my model means that the point elasticity has to be approximated. The formula used, adapted from the definition in equation [51] above, is:

$$\varepsilon_{NPV\ wrt\ \theta} = \frac{\Delta NPV}{\Delta \theta} \cdot \frac{\theta}{NPV} \qquad [\ 52]$$

Where θ represents any parameter. Each parameter was varied by increasing it 1%, in order to measure ΔNPV and $\Delta\theta$ for a small interval and approximate the point elasticity.

3.4.2. Scenario analysis

Scenario analysis is an important component in the sensitivity analysis employed in the thesis, as it allows for more coherent and comprehensible storytelling than does the piecemeal approach of partial sensitivity analysis. Below, the different scenarios used are outlined. Relevant outputs from running the scenarios are presented in the results section. Please note that the main focus is put on "best case" type scenarios, as the NPV results in the base scenario are grim enough without any worst case assumptions.

The following generic scenarios are used for analysis in the thesis:

- Low cost PV
- Low and high discount rate
- High abatement cost savings
- Investor best case
- Decision rule showcase

Low cost PV

The "Low cost PV" scenario consists of dramatically reduced prices on solar PV modules. This could be achieved simply by postponing project start by 5-10 years, as the prices on solar PV modules have fallen drastically over the last few years, and this trend is expected by experts to continue (see e.g. Rüther & Zilles 2011). In this specfic scenario, the price on PV modules is thought to fall with 16% p.a. for the next few years, corresponding to the trend the last calendar year (Solarbuzz 2011). The project is thought to be postponed 5-6 years, such that the PV module price has fallen to 1.20 USD/Wp, for a total drop of just above 62% from the start of the waiting period to the period end.

High and low discount rates

The discount rate scenarios fulfill the standard sensitivity analysis requirement of investigating the impact of higher and lower discount rate on the NPV of the project, looking into the impacts of a doubled and a halved discount rate for all players.

Table 3.6: Discount rate scenarios.

Scenario	Content	Levels of analysis affected
Low discount rate	Discount rate down 50%	All
High discount rate	Discount rate doubled	All

High abatement costs

The high abatement costs scenario increases the abatement costs by an order of magnitude, taking it to the extreme in order to investigate how influential abatement cost savings can be on the NPVs of Annex 1 country and the global community.

The investor best case

The investor best case scenario consists of:

- A 50% reduction in CDM TCs
- A CER price of 25 USD/tCO2e
- A 50% increase in all electricity prices (the prices paid by the host increase correspondingly, but the WTP for electricity in rural areas are not increased, instead it is assumed that the government subsidizes the increase)
- PV module prices equal to the prices in the “Low cost PV” scenario, and a 20% decrease in rigging and testing costs

Decision rule showcase

As put in the literature section, I was ready to commit a number of sins in order to investigate the nature of the decision processes underlying CDM project commitment. A quick glance at NPVs in the base scenario in the results section clearly determines that sinning is not enough, so with the *Decision rule showcase* scenario I turn to graver atrocities: the scenario is constructed with utter disregard for realism, concentrating instead on achieving positive NPVs for all players across all project alternatives. The presence of positive NPVs gives a chance demonstration on how to use the threshold value relationships derived in methodology section 3.3 to investigate the effects of uncertainty. The scenario consists of the following changes:

- 80% reduction in PV module prices and 20% decrease in rigging and testing costs.
- Investor discount rate reduced to 7% (less than half of the original value).
- CER price of 40 USD/tCO2e.
- Electricity prices in the *Grid* and *Diesel* scenarios are doubled.
- Abatement costs savings are increased to 25 USD/tCO2e.
- Host-related TCs are set to 5% of the solar PV plant investment costs, to simulate steep corruption and bureaucracy related costs[33].

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[33] As mentioned in the section 9.3, the data appendix, Henderson and Kuncoro (Henderson & Kuncoro 2011) estimate a corruption cost of 7% of manufacturing costs for manufacture firms in Indonesia, so 5% of investment costs when including both taxes and bribes might not be too farfetched.

- Host OCs are increased by an order of magnitude.

Given the assumptions in this scenario, the CDM-related TCs are investigated, by looking at the elasticities of the threshold values with respect to the CDM-related TCs.

4. Data

This section is meant to give a bird's eye view of the data used for quantification in this thesis. For the complete walkthrough, please consult section 9.3.

4.1. General observations about the data

All the data used in this thesis are sampled from other sources, and not many of the estimates used are site or project specific. As such, the quantification in this thesis can be viewed as a pre-feasibility study at best. The CBA results are expected to be roughly in the same neighborhood as the true values, but not more than roughly so. Direct use of the NPV results is done at the user's own peril.

4.2. Some key parameters

Some key parameters are reproduced in below, grouped by which player that initially is affected by the parameter. The main purpose of the tablse is to draw attention to some of the key parameter estimates, not to present a complete list of parameters. Parameters given in the tables below are based on estimates found in section 9.3 and own calculations.

Table 4.1: Investor parameter estimates. Sources: See section 9.3.

Parameter	**Estimate**
r, the risk free interest rate	3.17%
z, risk premium for South-Eastern Asia	12%
TC_{1j0}^{indo}, start-up related TCs in Indonesia	6 490 USD
TC_{1j0}^{cdm}, TCs of CDM application	505 800 USD
R_{1jt}^{el}, yearly power-selling revenues, *Grid* and *Replace diesel* scenario	1 429 083 USD
R_{13t}^{el}, yearly power-selling revenues, *No grid* scenario	8 385 533 USD
R_{11t}^{cdm}, yearly CER-revenues, *Grid* scenario	147 826 USD
R_{12t}^{cdm}, yearly CER-revenues, *Replace diesel* scenario	152 727 USD
$C_{1jt_{start}}^{build}$, plant construction costs, *Grid* and *Replace diesel* scenarios	45 571 500 USD
$C_{13t_{start}}^{build}$, plant construction costs, *No grid* scenario	52 725 355 USD
C_{1jt}^{maint}, yearly maintenance costs, percentage of revenue	10%

While Table 4.1 above detailed the parameter estimates for the investor, Table 4.2 below details the parameter estimates for the host country. As with all the estimates given here, the ones for the host country are derived from the data presented in section 9.3, in combination with own calculations.

Table 4.2: Host country parameter estimates. Sources: See section 9.3.

Parameter	**Estimate**
δ_2, Indonesian discount rate	10.6%
B_{2j0}^{tax}, pre-implemantation tax levied on the investor	5 010 USD
B_{2jt}^{tax}, yearly profit tax levied on the investor, percent of profits	37.3%
OC_{220}^{indo},OC of GOI officials' time, year zero	735 USD
B_{2jt}^{invest}, benefits from reduced investment need in the power sector	1 329 000 USD
B_{23t}^{el}, yearly benefits from earlier rural electrification	8 373 456 USD
C_{2jt}^{el}, yearly electricity costs in the *Grid* and *Replace diesel* alternatives	1 427 025 USD
C_{23t}^{el}, yearly costs of electricity in the *No grid* alternative	8 373 456 USD

As for the Annex 1 country, most of the parameters used are already given in the investor-table. But here are the main parameters that are new at the Annex 1 level:

Table 4.3: Annex 1 country parameter estimates. Sources: See section 9.3.

Parameter	**Estimate**
δ_3, Annex 1 country discount rate	3.0%
B_{31t}^{abate}, yearly saved abatement costs, *Grid* alternative	18 700 USD
B_{32t}^{abate}, yearly saved abatement costs, *Replace diesel* alternative	19 320 USD

Finally, the global community as well is almost entirely made up of parameter estimates from taken from the other players. The main parameters unique to the global community are reproduced in Table 4.4 below.

Table 4.4: Global community level parameter estimates. Sources: See section 9.3.

Parameter	**Estimate**
δ_4, global community discount rate	3.0%
OC_{4j0}^{cdm}, OC of CDM staff's time, year zero	18 570 USD

5. Results and preliminary interpretations

In this section, the main results of the thesis are presented and given a rudimentary interpretation in passing. This is done in order to narrow the field and focus on the most interesting parts rather than just mindlessly producing a hefty number of tables.

Summary tables are provided for the most essential findings. For ease of reading, the results for the players are presented head-to-head, in order to facilitate cross-comparison. For more detailed background information, the interested reader is encouraged to consult the appendix on null alternatives, given in section 9.2.

5.1. Basic NPV and threshold results

Table 5.1: Basic profitability results under certainty.

		Placement alternative		
Variable	**Player**	**Grid**	**Replace diesel**	**No grid**
NPV of project	Investor	-42 828 697	-42 818 579	-36 349 811
	Host	8 150 032	5 257 144	6 611 579
	Annex 1	-36 182 047	-36 206 005	4 879 623
	Global community	-34 773 819	-24 136 581	1 209 976
Profitability index (PI)	Investor	-0.9294	-0.9291	-0.6828
	Host	..	..	..
	Annex 1	-0.7851	-0.7857	0.0917
	Global community	-0.7543	-0.5235	0.0227
Internal rate of return (IRR)	Investor	-6.205 %	-6.188 %	3.720 %
	Host	..	..	..
	Annex 1	-7.163 %	-7.177 %	3.720 %
	Global community	..	-2.352 %	3.328 %

The main message in Table 5.1 is the payoff-ranking of the different project alternatives, and how it differs across players.

First things first: as the payoffs to the investor are all negative here, there will be no investment, not under the current conditions, at least. This can be considered a loss for the other players, as they all have a positive payoff to gain from at least one of the project alternatives. The host country is at the biggest loss, as the payoffs to the host country are the largest, and also because the payoffs to the host country are positive across all alternatives.

Looking a bit deeper, there is a clear similarity between the investor, the Annex 1 country and the global community. Namely that the payoff ranking of the investor, the Annex 1 country and the global community is somewhat similar, in the sense that the *No grid* alternative is the most profitable alternative for all these players[34].

The host country on the other hand, finds investment in the *Grid* alternative to be most profitable, and investments in the *Replace diesel* alternative to be least profitable. The latter comes as no surprise, given that null alternative specifies that there would be no investment in power replacing the diesel aggregates in the absence of a solar PV plant investment. Thus, the *Diesel* alternative comprises no power investment savings for the GOI. As discussed further in section 9.2, this is seen as reasonable, as the GOI has more pressing concerns to deal with than to replace fully functional (albeit polluting and expensive) diesel aggregates.

However, as far as the host country is concerned, the differences in payoff between scenarios are not that large. Considering that the null alternative payoff is zero, and that the *No grid* alternative is the most promising alternative to all the other players, it seems reasonable to assume that if the host country behaves rationally, it would cooperate in making investment in the *No grid* alternative happen. Following this line of reasoning, the *No grid* alternative stands out as the only alternative in which it might be realistic that investment in a solar PV plant in Indonesia could happen.

In order to make the *No grid* alternative a viable option for the investor, *ceteris paribus*, some sort of additional payments from the other players to the investor must be introduced in order to push the investor’s project payoff over the profitability threshold. At the base scenario level of payoffs in the *No grid* alternative as presented in Table 5.1, however, the payoffs to the host country, the Annex 1 country and the global community *combined* are not enough to compensate for the current negative negative payoff to the investor. Thus, there is not even a remote chance that the other players can collaborate in compensating the investor and still

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[34] That is, if the investor is forced to choose between the placement alternatives, he or she would prefer the *No grid* alternative, as it is the least unprofitable alternative from the investor’s point of view.

have a surplus to divide between them. The robustness of this conclusion is investigated section 5.2, along with the robustness of the individual payoffs.

As for the threshold values in the base scenario, I focus on the ones that are relevant, namely the *No grid* alternative and the players that have positive payoffs – as decision rules for negative payoffs are irrelevant[35]. Further, the threshold values are

Table 5.2: Selected threshold value results for the base scenario.

Variable	**Player**	**No grid alternative**
$\overline{p^{comc}} = \overline{p^{com,B}}$	Host	-0.065 %
	Annex 1	0.133 %
	Global community	0.594 %

The results in Table 5.2 above need some interpreting as far as the host country probabilities are concerned. The NPVs and GNPVs for the host country are all positive, and the reason why the threshold values are negative, is actually that tax benefits are larger than OCs of the time of the GOI officials. Thus the negative threshold value for the host corresponds to an auto-yes threshold value.

The Annex 1 country and global community thresholds indicate that the effects of uncertain host country approval are small to none. The reason for this is simple: the estimated host country related TCs are of negligible size compared to the player payoffs. Further, it as expected that the global community threshold value is higher than the Annex 1 country threshold value, as the global community take the OCs of the host country into account.

5.2. Partial sensitivity results

Partial sensitivity results are presented in this section, with one subsection devoted to each player. A brief interpretation of the most important findings is provided at the end of each subsection.

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[35] When the NPV for the certain outcome is negative, this constitutes an auto-no rule both under certainty and under uncertainty.

5.2.1. Investor elasticities

Table 5.3: Investor NPV elasticities.

Parameter	Point elasticity NPV			Sign of $\partial NPV/\partial\theta$		
	Grid	**Replace diesel**	**No grid**	**Grid**	**Replace diesel**	**No grid**
Size in MW, peak	0.9874	0.9874	0.9977	-	-	-
Discount rate	0.0955	0.0958	0.5504	-	-	-
CER price, USD/tCO2e	0.0071	0.0074	..	+	+	..
TC CDM	0.0118	0.0118	..	-	-	..
Tau (CER-payment delay)	0.0041	0.0042	..	-	-	..
Average feed in tariff	0.0689	..	..	+	..	..
Average price dieselpower	..	0.0689	..	..	+	..
Average WTP for power	..	..	0.4762	..	..	+
Cost of PV modules	0.7448	0.7450	0.8776	-	-	-
Cost of batteries	..	..	0.2223	..	..	-
Transport	0.0532	0.0532	0.0627	-	-	-
Rigging and testing	0.2660	0.2661	0.3134	-	-	-
Indonesia-related TCs	0.0002	0.0002	0.0002	-	-	-
Profit tax	0.0538	0.0540	0.3370	-	-	-
Revenue delay (years)	0.0310	0.0311	0.1836	-	-	-
Electrical effience of plant	0.0760	0.0763	0.2539	+	+	+
Technical loss in plant	0.0253	0.0254	0.0846	-	-	-

The point elasticity of the plant size itself seems to be the most influential, in all scenarios. This is not surprising, as the plant size determines the size of pretty much all other payments. What is more surprising is the fact that the rate of change is negative, meaning in essence that the bigger the plant is, the more the investor is going to lose. These increasing losses in turn indicate that at the price current price per kWh and the current volume of electricity sold, the investor is not able to recover his or her average costs per kWh. Increased unit price, increased sales volume and/or decreased investment costs are needed in order to reverse the negative relationship.

The influence of the CDM-related variables also has to be mentioned. In short, the influence appears to be unimportant. The revenues achieved from the CERs are too small to make a difference when the main building blocks to attain profitability – solar PV module price and price of electricity – are not present. In fact, CER-price has to be about 2,300 USD/tCO2e in both the *Grid* and the *Replace diesel* alternative in other to achieve a zero NPV for the project. This is unattainable carbon prices[36], as the pollution constraint needed to attain them would be so strict that it would surely be vetoed in international negotiations. These impossibly high CER-prices point toward the simple fact that CDM revenue is not enough on its own to ensure project profitability. This observation of the marginal nature of the CDM seems well in line with the literature (see e.g. Bode & Michaelowa 2003), and, sadly, the solar PV project alternatives as they are presented in this thesis are not just *marginally* unprofitable.

Regarding the difference between the placement alternatives, it appears that there is a tendency that most of the parameters are more influential in the *No grid* scenario. This is only natural, as the NPV is smaller (in absolute value) than for the other alternatives. But it does point towards a fact that could be easy to overlook amidst all the changing of scenarios which will be introduced in the coming sections, and that is that the elasticities for all variables will change between scenarios, and thus the elasticities presented in the base scenario will not be directly applicable in any of the other scenarios.

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[36] To put ting into perspective, Tol (2008) argues that if a carbon price liability in the neighborhood of 20-30 USD/tC where to be implemented on a worldwide basis overnight, it would result in the world economy going bankrupt.

5.2.2. Host country elasticities

Table 5.4: Host country NPV elasticities.

Parameter	Point elasticity NPV			Sign of $\partial NPV/\partial\theta$		
	Grid	Replace diesel	No grid	Grid	Replace diesel	No grid
Size in MW, peak	1.0444	0.9928	1.1193	+	+	+
Discount rate	0.6342	1.0039	0.5166	+	-	+
Average feed in tariff	0.6727	..	..	-	..	..
Average price diesel	..	1.0428	..	..	-	..
Average price rural	..	..	4.8656	..	..	+
Costs of Indonesian plants	1.6307	..	0.6000	+	..	-
Electrification benefits	..	..	5.2649	..	..	+
Healt effects	..	1.9756	..	..	+	..
Profit tax	0.4426	0.6883	2.9012	+	+	+
t-start (revenue delay)	0.1815	0.2873	0.2873	+	-	-
OC of host	0.0001	0.0001	0.0001	-	-	-
Pre-tax	0.0006	0.0010	0.0008	+	+	+

The most influential parameter in the *Grid* alternative is the costs of investing in power plants in Indonesia. This is easy to explain; the parameter represents a substantial year zero benefit in a society using high discount rates. But the positive payoff is rather robust to changes in even this parameter; it takes a 61% decrease in the power plant costs in order to set the payoff in the *Grid* alternative equal to zero.

Health effects are most influential in the *Replace diesel* alternative, and this makes perfect sense, as in this alternative there is no benefits from reduced investment needs. However, the fact that the health effects are most influential gives every reason to suspect the validity of the *Replace diesel* NPV, as health effects are one of the more uncertain parameter estimates in this thesis.

Finally, in the *No grid* alternative, the most influential parameters are the price paid for electricity and the electrification benefits enjoyed by the rural community, these are de But in the *No grid* alternative as well, relatively small changes in the price of electricity renders the host country payoff equal to zero.

5.2.3. Annex 1 country elasticities

Table 5.5: Annex 1 country NPV elasticities.

	Point elasticity NPV			**Sign of $\partial NPV/\partial\theta$**		
Parameter	**Grid**	**Replace diesel**	**No grid**	**Grid**	**Replace diesel**	**No grid**
Size in MW, peak	0,9836	0,9836	1,0857	-	-	+
Discount rate	0,1028	0,1024	4,4028	-	-	-
Abatement cost savings	0,0073	0,0075	..	+	+	..
TC CDM	0,0140	0,0140	..	-	-	..
Tau (CER delay)	0,0266	0,0275	..	+	+	..
Average feed in tariff	0,2936	..	..	+	..	..
Average price of diesel	..	0,2934	..	..	+	..
Average WTP for power	..	..	12,7758	..	..	+
Cost of PV modules	0,8817	0,8811	6,5374	-	-	-
Cost of batteries	..	..	2,43531	..	..	-
Indonesia-related TCs	0,0002	0,0002	0,0013	-	-	-
Profit tax Indonesia	0,2293	0,22989	9,04244	-	-	-
Revenue delay (years)	0,0239	0,0238	1,0316	-	-	-

The most influential variable in the *Grid* and the *Replace diesel* project alternatives is the size of the plant, followed by the price of solar PV modules, both with a negative effect on the profitability of the project.

In the *No grid* alternative the WTP for electricity the NPV is generally more elastic with respect to all the parameters; actually, the only parameter for which the NPV is inelastic here is the host-related TCs. The most influential parameter by far is the WTP for electricity in rural areas, which affects revenues to the investor, and since this revenue is internalized by the Annex 1 country, the WTP becomes important also to the Annex 1 country. Actually, a reduction in WTP of just 7.8%, i.e. a decrease of about 0.055 USD/kWh, sets the NPV equal to zero.

The profit tax in Indonesia is also influential on the results in the *No grid* alternative, again due to the revenue link between the Annex 1 country and the investor. Almost needless to say, the cost of solar PV modules and batteries are also important here. But it is interesting to see that even though batteries are expensive and replaced mid-period in the model, the modules are still the most influential factor on the NPV.

The CDM-related parameters are not very influential here either, just as for the investor. One curious effect is worth noting however: delayed first issuance of CERs actually increases the overall profitability of the project, in both the *Grid* and *Replace diesel* alternatives. This is due to the fact that the Indonesian taxes on the investor and plant operation costs are counted as costs in the Annex 1 model (since the taxes are reducing the amount of money the investor can re-invest in the home country), and in the quantification done here, the sum of the two negative effects is apparently larger than the abatement cost savings. As the payments are considered to be constant, we can deduce that the abatement cost savings are cancelled out by the revenue tax in all the periods, meaning that electricity revenue from the investor is main positive driver behind the Annex 1 country NPV results in the *Grid* and *Replace diesel* alternatives, a somewhat surprising result given that the main reason for the existence of the CDM is supposed to be to contribute to cost-effective abatement. Given this reason, it seems somewhat ironic that the abatement cost savings are not the most important contributor to Annex 1 profitability. But, as already mentioned, the abatement cost savings are probably too conservatively estimated in the base scenario, so the impact might change in some of the other scenarios considered in section 5.3.

5.2.4. Global community elasticities

Table 5.6: Global community NPV elasticities

Parameter	**Point elasticity NPV**			**Sign of $\partial NPV/\partial\theta$**		
	Grid	**Replace diesel**	**No grid**	**Grid**	**Replace diesel**	**No grid**
Size in MW, peak	0.9852	0.9705	1.2587	-	-	+
Discount rate	0.0212	0.3417	9.2565	+	-	-
Abatement cost savings	0.0076	0.0113	..	+	+	..
TC CDM	0.0145	0.0210	..	-	-	..
OC CDM	0.0005	0.0008	..	-	-	..
Tau (CER issuance delay)	0.0221	0.0329	..	+	+	..
Health effects	..	0.9913	..	..	+	..
Cost of Indonesian plants	0.3822	..	7.7037	+	..	+
Electrification benefits	..	..	39.6048	..	..	+
Cost of PV modules	0.9174	1.3216	26.3642	-	-	-
Indonesia-related TCs	0.0002	0.0003	0.0054	-	-	-
OC Indonesia	0.0000	0.0000	0.0006	-	-	-
Revenue delay (years)	0.0049	0.0795	3.8955	+	-	-

The most influential parameter in the *Grid* alternative is the size of the plant, closely followed by the cost of PV modules. Just as for the Annex 1 country both these parameters reduce the profitability of the project, indicating that “size does matter”, but in the wrong way – the bigger they are, the harder they fall.

When it comes to the *Replace diesel* alternative, the cost of solar PV modules is the most influential parameter, followed by health effects and then the size of the project. As discussed in the host country section, the health effects are based on a rather uncertain estimate, and so the diesel alternative becomes somewhat suspect when it the health effects are so influential relative to the other variables.

A special note has to be made on the positive sign of the rate change of the NPV with respect to delayed first issuance of CERs. This occurs both in the grid and the diesel alternative, and the reason for it is that the maintenance costs to the investor are internalized by the global community. The maintenance costs are in turn dependent on the investor revenues in each period, due to the fact that the model is built in a way such that the maintenance contract demands a percentage of the investor revenues in each period. Implicit in the positive rate of change, then, is the fact that the increase in maintenance costs due to increased investor revenues is bigger than the abatement cost savings in each period. As mentioned in the Annex 1 country section, this appears as somewhat of a paradox given that cost-effective abatement is considered one of the main reasons for the existence of the CDM. But, as already mentioned, the estimate used for abatement cost savings in this thesis is too conservative.

In the *No grid* alternative, the elasticities with respect to the influential parameters are in general much higher than in the other two alternatives, clearly demonstrating that the NPV result obtained is very fragile. The electrification benefits are most influential, while the cost of the solar PV modules comes in second, both with a two digit elasticity figure.

5.3. Scenario results

The results from the scenarios are presented below, with the results for each player in a separate subsection.

5.3.1. Investor best case scenario

Below are the results for the investor best case scenario.

Table 5.7: Investor best case scenario NPVs.

		Placement alternative		
Variable	**Player**	**Grid**	**Diesel**	**No grid**
NPV of project	Investor	-17 292 858	-17 277 621	3 138 376
	Host	2 838 753	-48 461	-25 557 810
	Annex 1	-3 878 288	-3 918 795	89 399 212
	Global community	-14 716 762	-4 083 023	11 559 142
Profitability index (PI)	Investor	-0.7311	-0.7305	0.1019
	Host	..	..	..
	Annex 1	-0.1622	-0.1639	2.8784
	Global community	-0.6151	-0.1707	0.3719
Internal rate of return (IRR)	Investor	2.745 %	2.764 %	16.963 %
	Host	..	..	..
	Annex 1	1.624 %	1.609 %	16.963 %
	Global community	..	1.548 %	8.628 %

As can be read from the above table, the investor best case scenario renders the investor payoff in the *No grid* alternative positive. It is interesting to see that this happens at the expense of the host country profitability, indicating a conflict of interest between the two players. Also worth noting is the fact that while the size of the investor payoff is rather small, the Annex 1 country wins on a massive scale.

5.3.2. Decision rule showcase scenario

Though it is not the main case here, the basic NPV-related indicators are presented in Table 5.8 below, for reference.

Table 5.8: Decision rule showcase scenario NPVs.

		Placement alternative		
Variable	**Player**	**Grid**	**Diesel**	**No grid**
NPV of project	Investor	3 471 873	3 526 926	18 153 872
	Host	3 656 756	779 673	7 124 029
	Annex 1	10 501 051	10 526 376	39 452 038
	Global community	358 834	11 081 710	35 775 776
Profitability index (PI)	Investor	0.3016	0.3064	0.9726
	Host	..	..	..
	Annex 1	0.9122	0.9144	2.1137
	Global community	0.0311	0.9605	1.9140
Internal rate of return (IRR)	Investor	9.544 %	9.581 %	14.423 %
	Host	..	..	..
	Annex 1	8.726 %	8.738 %	14.423 %
	Global community	1.233 %	8.972 %	20.054 %

As can be seen above, the NPVs all present healthy positive values, indicating automatic project go-ahead in a world without uncertainty and budget constraints.

In Table 5.9 on the next page, the corresponding threshold values are presented, shattering somewhat the idyllic picture from Table 5.8.

Table 5.9: Decision rule showcase scenario threshold values.

Variable	**Player**	**Placement alternative**		
		Grid	**Replace diesel**	**No grid**
P1 - comm w/o CDM uncert	Investor	22.877 %	22.601 %	2.806 %
	Host	Auto-yes.	Auto-yes.	Auto-yes.
	Annex 1	8.931 %	8.912 %	1.311 %
	Global community	74.634 %	8.699 %	1.464 %

P2 - CDM-appl	Investor	40.067 %	39.419 %	..
	Host	..	..	..
	Annex 1	40.131 %	39.482 %	..
	Global community	40.861 %	40.200 %	..
P3A - comm w/ uncert pt A	Investor	39.620 %	39.702 %	..
	Host	..	..	..
	Annex 1	11.757 %	11.843 %	..
	Global community	91.641 %	11.398 %	..
		-36.684 %	-285.463 %	..
P3B - comm w/ uncert pt B	Investor	38.789 %	40.262 %	2.806 %
	Host	Auto-yes.	Auto-yes.	Auto-yes.
	Annex 1	6.246 %	6.305 %	1.311 %
	Global community	-30.789 %	5.976 %	1.464 %

Some of the global community threshold values also need some explaining, namely the $\overline{p_4^{com,B}}$ and the two-parted threshold value $\overline{p_4^{com,A}}$. As for $\overline{p_4^{com,B}}$, the negative value implies an auto-no rule, as it is basically the CDM-related benefits that render the NPV positive with the current value of the parameters. When it comes to the two parts presented in $\overline{p_4^{com,A}}$, they are a result of the quadratic expression that had to be untangled in order to obtain $\overline{p_4^{com,A}}$ (consult section 3.3 for more). Both values are valid, in the sense that both are a part of the mathematical answer. But in application the negative values in Table 5.9 above are trivial, and so we focus on their positive counterparts.

Leaving the technical explanations behind, Table 5.9 gives a testament to the importance of uncertainties, especially related to the CDM, as projects with clearly positive NPVs will be chosen only for some given threshold, at times a rather substantial threshold. The global community in the *Grid* alternative gives a particularly striking example. $\overline{p_4^{comc}} = 74.6\%$ means that the global community would turn down projects with a certain CDM approval even if the outcome were 70% certain, and similarly it would commit to a project with uncertain CDM approval only if $\widehat{p_4} \geq 91.6\%$. This is pretty striking results, brought forth by the fact that fact that in the *Grid* alternative, the global community NPV is negative when CDM-related benefits and costs are not counted in.

Due to larger NPVs and GNPVs, the results for the Annex 1 country and the investor are less intimidating than for the global community. The biggest threshold values found in Table 5.9 for the Annex 1 country and the investor lie about 40%. If you as an investor have done your homework in your feasibility study and your *ex ante* valuation of the project, you should be more than 40% certain on project success when you commit.

To illustrate the concept of the threshold values and relate it to the overall expected payoff of the project, the expected payoff is graphed as a dependent variable and p as the independent variable. The result is shown in Figure 5.1 below. The graph is for the investor, in the *Decision rule showcase* and the *Grid* alternative. As this graph is meant chiefly for illustrative purposes, no graphs for the other players and project alternatives are produced, as these graphs will be similar to the one in Figure 5.1, only with slightly different slopes and intercepts.

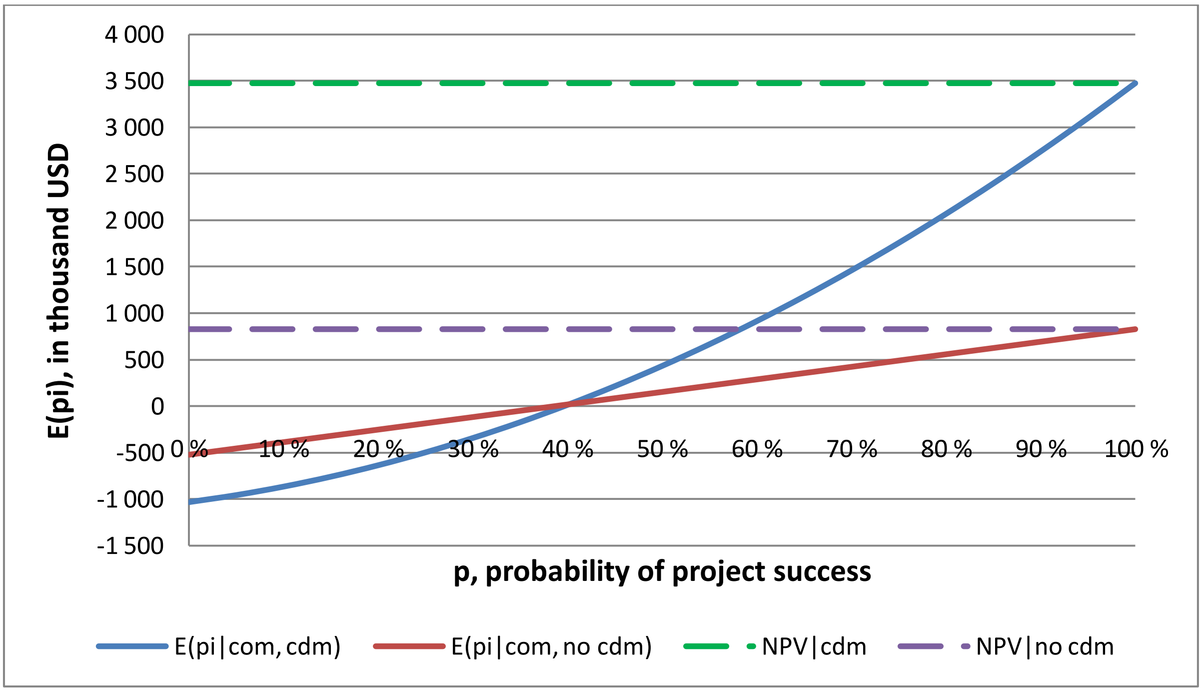

Figure 5.1: Payoff versus success probability for the investor, in the *Decision rule showcase* scenario.

The blue line represents the expected payoff of commitment given application for CDM status, $E(\pi_{11}|\text{CDM appl})$, while the red line represents the expected payoff of commitment given no CDM application, $E(\pi_{11}|\text{no CDM})$. The dashed green line represents the payoff under certainty, in other words the regular NPV, with CDM related costs and benefits, while the dashed purple line represents payoff under certainty, but without CDM related costs and benefits. The point where the curves intercept the x-axis correspond to the threshold values for p.

5.3.3. The other scenarios

Table 5.10 presents NPVs for the simplest scenarios. The results are interpreted in brief below the table. The host NPVs are not reproduced in the *High abatement cost savings* scenario and the *Low cost PV* scenario, as they are unchanged from the base scenario.

Table 5.10: NPVs of other scenarios.

		Project alternative NPVs		
Scenario	**Player**	**Grid**	**Replace diesel**	**No grid**
Low cost PV	Investor	-22 928 697	-22 918 579	-16 449 811
	Annex 1	-16 282 047	-16 306 005	24 779 623
	Global community	-14 873 819	-4 236 581	21 109 976
High abatement cost savings	Annex 1	-33 807 734	-33 752 968	..
	Global community	-32 399 505	-21 683 543	..
Low dicount rate	Investor	-39 374 480	-39 353 626	-19 535 608
	Host	4 321 423	9 166 598	1 344 794
	Annex 1	-34 068 415	-34 097 487	17 108 662
	Global community	-35 192 356	-19 447 595	7 134 071
High discount rate	Investor	-44 922 273	-44 918 663	-46 711 305
	Host	11 111 012	2 233 640	5 927 865
	Annex 1	-39 150 820	-39 167 594	-12 246 274
	Global community	-34 185 948	-30 722 651	-8 832 941

The *Low cost PV* scenario shows clear improvements in payoffs compared to the base scenario payoffs in Table 5.1. And although the ranking of payoffs is the same for each of the players, and the investor payoffs remain all negative, there is some light in the tunnel: the payoffs are now so large for the Annex 1 country that it compensate the investor's losses in the *No grid* alternative on its own, and still enjoy a positive profit from the project. Note, however, that the Annex 1 country NPV in the *No grid* scenario still is very sensitive to changes in the main parameters. As an example, just a 13.4% decrease in the electricity price is enough to reduce the Annex 1 country NPV to a positive value marginally smaller in magnitude than the negative NPV of the investor.

Regarding the *High abatement cost savings* scenario, it proves that the high abatement cost savings in themselves are not enough to ensure project profitability, as increasing abatement cost savings with one order of magnitude does not change the result from the base scenario, that the *Grid* and *Replace diesel* alternatives both have massively negative payoffs for both the Annex 1 country and the global community. Actually, increasing abatement costs with two orders of magnitude, to a whopping 210 USD/tCO2e, does not alter the conclusion that the *No grid* alternative is the preferred alternative to both the Annex 1 country and the global community. The changes brought on by the two orders of magnitude increase is only that the *Replace diesel* scenario now yields a small positive profit for the global community; the *Grid* alternative payoffs are of course pushed closer to profitability, but they remain negative for both the Annex 1 country and the global community, and the *Replace diesel* scenario payoff remains negative for the Annex 1 country. All in all, the attempted conclusion that the reduced abatement costs are not the main contributor to project profitability, as made while interpreting the base scenario in section 5.1, seems to be quite robust to parameter changes.

In the *Low discount rate* the order of project alternatives from most to least profitable is, unsurprisingly, unchanged for the investor and the Annex 1 country. The scenario does not change the sign on any of the player payoffs. But, as can be seen in Table 5.10, the Annex 1 country payoff in the *No grid* alternative is increased almost fourfold compared to the base scenario payoff – a reconfirmation of the sensitivity of how sensitive this payoff is to changes in any central parameters. On a different note, the scenario shows some results that might appear counterintuitive at first glance, namely that some of the players' NPVs decrease compared to the base scenario when the new, lower discount rate is applied. Affected NPVs include: the host country NPVs for the *Grid* and the *No grid* alternative; and the global community NPV in the *Grid* alternative. For the host country, the explanation is simply the structure of the cash flows; in the *Grid* and *No grid* alternatives, the benefits accrue at an early time, while the costs are evenly spread out across time periods, and thus a lower discount rate decreases the NPVs. This effect does not apply to the *Replace diesel* scenario, as in this scenario, benefits and costs to the host country are both spread evenly out across time periods, and thus the NPV actually increases with a lower discount rate, making the *Replace diesel* scenario the most profitable scenario to the host country in the *Low discount rate* scenario. For the global community, on the other hand, the reason for the decreased NPV in the *Grid* alternative, is that the net benefits in all periods are negative, and as a lower discount rate increases the impacts of all future periods, the lower discount rate here results in a decrease in the overall NPV.

Having dealt with the *Low discount rate* scenario, the *High discount rate* scenario can be summarized simply as the mirror image of the former. Again, no big changes in payoff structure occur. Actually, the payoff structure of the host country is reinforced, as opposed to the change that occurred in the *Low discount rate* scenario. Another change that is worth special mentioning is the global community and Annex 1 country payoffs in the *No grid* scenario, as these payoffs change signs from positive in the base scenario, to negative in the *No grid* scenario. This change provides a nice illustration of the discount rate as one of the key differences between the investor and the Annex 1 country. Actually, if the investor's discount rate were equal to the Annex 1 country discount rate in the base scenario, the investor NPV in the *No grid* scenario becomes positive and *precisely* equal to the Annex 1 country NPV[37].

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[37] This is no wonder, as the NPV models of the two players are equal in everything except the discount rate in the *No grid* scenario.

6. Discussion

In this section, the main findings from the results section are coupled together with insights from the rest of the thesis and discussed as thoroughly as needed in order to "make the jump" from the results section and to the short answers to the RQs as they appear in the conclusion in section 7. Subsection 6.1 summarizes the main results from the quantification, while subsections 6.2-6.7 are organized into themes roughly corresponding to each of the RQs posed in the introduction.

6.1. Summary of main results from the quantification

A quick summary of the main findings from the results section is due before embarking on the discussion. The main results are as follows:

- The payoffs to the investor are negative across all alternatives in the base scenario, indicating that no investment will be made.
- The only project alternative that seems remotely viable is the *No grid* alternative, as this alternative exhibits positive payoffs for three of the four players (the host country, the Annex 1 country, and the global community).
- The sum of positive payoffs in the *No grid* alternative in the base scenario is not large enough to offset the negative investor payoff. However, the sum is large enough to offset the negative investor payoff and create an overall positive net payoff in the *Low cost PV* scenario.
- The positive payoffs are generally quite sensitive to changes in the parameters.
- Regarding the effects of uncertain CDM-approval and project success, their effects on project commitment seem low, but the "discount effect" on expected project profits could be sizable.

6.2. Project profitability

The possibilities for deriving profits from solar PV projects in Indonesia appear slim, especially for the investor. In the base scenario, none of the investigated project alternatives yield profitability for the investor[38]. And even in the most extreme of the (somewhat) realistic positive scenarios, that is, the *Investor best case* scenario, only the *No grid* project alternative

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[38] This is in line with the results obtained by Schneider et al. (2010).

gives a positive NPV for the investor. And this positive NPV result is small in comparison to the invested amount of money, with a PI of about 0.10 (meaning 10 cents gained per invested dollar). The small relative size of this profit also renders it vulnerable with respect to changes in the parameters, and thus makes even this project payoff somewhat of a gamble for the investor, given the inherent uncertainties in any *ex ante* project evaluation.

The other players are marginally better off compared to the investor. For the global community and the Annex 1 country it is the *No grid* project alternative that stands out, just as for the investor. Due largely to the low discount rates used by the Annex 1 country and the global community, the *No grid* project alternative is profitable to these players already in the base scenario. However, the apparent overall winner in the base scenario is the host country; due to low electricity prices paid by the citizens in combination with reduced need for own power sector investments and non-market health benefits and electrification benefits, all project alternatives give positive NPVs for the host country in the base scenario. But this does not help much when the agent making the investment decision, the investor, sees no profit in any of the project alternatives.

6.3. Influential parameters

Drawing upon the results from the partial sensitivity analysis, together with some general observations from the scenario analysis, the following set of key parameters emerges for the different players and project alternatives:

Table 6.1: Influential parameters in the base scenario.

Alternatives	**Investor**	**Host country**	**Annex 1 country**	**Global community**
Grid	*Positive:* Electricity price *Negative:* Low feed-in tariff Module costs	*Positive:* Investment savings *Negative:* Electricity price	*Positive:* Electricity price *Negative:* Module costs	*Positive:* Cost of host power plants *Negative:* Module costs
Replace diesel	*Positive:* Electricity price *Negative:* Module costs	*Positive:* Health effects *Negative:* Electricity price	*Positive:* Electricity price *Negative:* Module costs	*Positive:* Health effects *Negative:* Module costs
No grid	*Positive:* Electricity price *Negative:* Module costs	*Positive:* Electrification benefits *Negative:* Electricity price	*Positive:* Electricity price *Negative:* Module costs	*Positive:* Electrification benefits *Negative:* Module costs

The investor-related results are consistent with the results found in Schneider et al. (2010), namely that it is the price of electricity that is the most influential variable. Unsurprisingly, the cost of solar PV modules is the most influential variable in the negative sense.

No yardstick literature findings are available for the host country, but the findings here as well seem reasonable, although they are crucially dependent upon the time preferences of the host country, in the sense that “renting” solar PV electricity capacity from foreign hands can only be profitable in competition with coal plants given a high preference for avoided year zero investments.

The Annex 1 country influential variables are identical to the ones for the investor, something which is to be expected given the large overlap between the two players (consult the Annex 1 country NPV-model in Eq [7] for proof).

The global community perspective naturally presents the most nuanced picture of the investment benefits and costs. Within the base scenario assumptions, the main picture is that it is the host country-related benefits that are most influential, not the CDM-related benefits. This coincides with two points made in the CDM-literature at large: first, that RETs have a huge potential for sustainable development benefits in the CDM host countries ; and second, my findings implicitly support the claims made in the literature that within the current CDM regime, incentives to implement RET projects in CDM host countries are too small (Paulsson 2009). On the cost side, the solar PV modules are most influential, proving again that the module costs are a major post in the overall NPV calculations.

6.4. Conflicting interests

The conflicting interests inherent in the solar PV investment case investigated in this thesis become apparent when we investigate further the potential for when the project could be profitable to the investor.

When it comes to investor profitability we must turn to the *Investor best case scenario*, a scenario that includes some rather strong assumptions regarding, among other things, electricity prices in the host country. As shown in the results section, the profitability to the host country is severely affected by the increased electricity prices. As the host country can be considered to be the one player other than the investor herself/himself that is crucial to ensure that the project becomes a reality, this is bad news, and it indicates the presence of a hidden zero-sum game incorporated in the "win-win-win-win-win" structure of the CDM[39]. A quick look at Table 5.8 in the results section (the NPVs in the *Investor best case* scenario) gives a clear feeling of a non-cooperative game. If we use the game framework established in methodology section 3.34 and presume that players have perfect information regarding the end payoffs, we can conclude that in the *Investor best case* scenario, the host country has every incentive to renegotiate the CDM in step (A) of the game, set different domestic

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[39] This rather over-the-top expression is coined by Lee et al. (1997, p viii), as they pronounce that ETS and the flexible mechanisms "provide win-win-win-win-win opportunities" for all the five players involved.

policies in step (B) of the game, or simply take strategic action in step (D) and block the investor from getting the project off the ground.

More generally, the investigations point towards the fact that both the investor and the Annex 1 country are interested in collecting high prices per kWh in order to ensure project profitability. While for the host country the opposite is true: low electricity prices paid to the investor are needed in order to ensure project profitability. In strategic interactions between the players, this is bound to become the subject of a considerable tug-of-war. If it is not a directly zero-sum game, it is probably close – though the "free" money offered by the selling of CERs certainly sweetens the pill and encourages cooperative behavior, this revenue stream is not sufficiently large to secure the promised "win-win-win-win-win"

With the Annex 1 country and the investor on one side, and the host on the other side, we have the basic setup of a non-cooperative game. Options for solving this are traditionally thought to be side payments or the Folk theorem (Romstad 2005). The Folk theorem seems less than ideal for application in this case. The theorem are supported by three main conditions, namely a specific payoff ranking for the agent, that the game is infinitely repeated (or has an unknown stop time), and that the agent has a sufficiently discount rate (Romstad ibid). Out of these three conditions, both the infinite repetition and the low discount rate assumption are not likely to be met; Indonesia as a host country has a very high SDR, and the CDM game is unlikely to be an infinitely repeated game. Ruling out the Folk theorem as a possible remedy leaves side payments as the only available venue for solving the impasse. But side payments as a solution creates problems of its own, regarding how to divide the economic surplus that the side payments represent between players (Romstad 2005), a basic negotiation and bargaining position related problem.

6.5. CDM contributions

The fact that the *No grid* alternative is the preferred alternative for those players that are thought to benefit the most from the CDM – the investor and the Annex 1 country – is a powerful message by itself. It is a message about the inability of CDM to provide sufficient support and incentives to RET projects in general, and solar PV projects in specific, in line with the general skepticism found in the literature towards the ability of CDM to deliver sustainable development (see e.g. Paulsson 2009 for an overview).

Actually, the contribution of the CDM to project profitability is positive for the investor, but not so for the Annex 1 country and the global community. Due to the low abatement cost savings assumed in the base scenario and the high CDM-related transaction costs, the net present value of all CDM-related costs and benefits are negative for both the Annex 1 country and the global community. This negative contribution to the Annex 1 country and global community are reversed when the abatement cost savings hit a value of just over 4 USD/tCO2e in the *Grid* alternative, and just under 4 USD/tCO2e in the *Replace diesel* alternative. The global community exhibit similar results, with values of 4.17 USD/tCO2e and 4.04 USD/tCO2e respectively. Although these CER-price increases represent roughly a doubling of the base scenario estimates, the values are probably still at the low end of the spectrum of likely abatement cost saving estimates. And thus it is natural to assume that the CDM in reality contributes positively to project profitability for the Annex 1 country and the global community.

Further, although the contribution of the CDM to investor profits is positive, it is small compared to the size of the project in amount of dollars invested. In other words, the CDM-related benefits are not the most influential parameter for any of the players affected by them. And this is a result that holds across all scenarios considered. As an example, CDM-related benefits are not nearly the most important effects for the Annex 1 country and global community even in the *High abatement cost savings* scenario. Actually, the abatement cost savings has to be increased to a size about two orders of magnitude larger than their initial value in order to push the Annex 1 country and global community profitability results anywhere near zero or positive profits for any of the project alternatives.

The effect of reducing CDM-related transaction costs has a similarly limited effect on project profitability, and again this can be attributed to the massive size of the negative profits relative to the size of the CDM-related benefits and costs, especially in the base scenario. Reducing the CDM related TCs in year zero with 90% yields a net gain in NPVs of about 455,000 USD. Such a gain is too small to really help the project studied here, but it might be highly influential in the marginally unprofitable projects, i.e., those projects that are on the verge of achieving profitability on their own merit. And this effect of making a difference for the marginally unprofitable projects is well in line with the underlying cost-effectiveness principle of the CDM. However, as proven through this case study on solar PV, the approach of only focusing on the least cost abatement opportunities destroys the possibility for realizing some projects with a positive NPV at the global level through the CDM, exemplified in the *No grid* alternative. The main benefits in the *No grid* alternative at the global level are non-market, sustainable development benefits. The fact that the CDM does not take these effects into account and fails to realize them, is well in line with the strand of literature that critiques the CDM as unable to deliver on its sustainable development goal in its current form (see e.g. Boyd et al. 2009; Sutter & Parreño 2007).

One final note on transaction costs has to be made, and that is that out of any of the CDM related parameters, TCs are the prime parameter to influence at the global community level in order to increase project profitability. The main reason for this is that TCs are the only parameter that is somewhat easy to change for a principal working at the global community level to influence project outcomes. The main reasons that the TCs are in this position are the unruly nature of the CER-prices, and the fact that TCs are incurred at project start, meaning that a reduction in these early costs are worth more to the investor than any discounted and uncertain benefits or costs further down the line in the project. A quick explanation about the "unruly nature" of the CER-prices is due. The main point of the term "unruly" is that although CER-prices are relevant to investor profitability and anchored at the global level at the same time, the CER-prices are not easily available for alteration. As CER-prices are market determined they can really only be increased through an increased demand and/or decreases in supply. Demand increases can only be achieved by either tightening the international emission constraints, or, by demand increases arising from other market forces, e.g. from an increase in world production, increasing industry needs for permits. The first of these sources of CER-price increase takes tough climate negotiations, while the second is simply governed by market forces outside of the direct control of any climate policy. When it comes to decreasing the supply, two approaches spring to mind as short run remedies: to strategically reject a number of CDM applications that are in fact eligible for CER issuance; or to introduce a separate, high-end market for CERs that promote sustainable development, like the "gold standard. The former of these would destroy any investor trust in the CDM as an institution, while the latter has been criticized academically (Paulsson 2009).

6.6. The effects of uncertainty

The effects of uncertainty on the CDM actors are modeled in the methodology section and quantified in the results section. The essence of the work done in this thesis regarding uncertainties, has been to model the expected project payoffs given risks of CDM rejection and project failure. These expected payoffs were then used to derive threshold values for the success probability that sets expected project payoff equal to zero. These threshold values can in turn be used as an additional decision rule for the players in the CDM game: no player should commit to a project if her or his subjective probability of project success is smaller than the given threshold value probability for project success.

Some main points are worth noting about the threshold values. First of all, they are extreme values, in the sense that they are the required values that sets the expected value of the project equal to zero. As such, that a 40% success probability (or, conversely, a 60% probability of failure) sets the expected project profitability to the investor equal to zero in the *Decision rule showcase* scenario is a non-trivial finding. The substantial discount effect that project uncertainty creates is underscored by the graphs in Figure 5.1, which clearly demonstrate the substantial differences in overall project profitability.

Further, evidence from the *Decision rule showcase* scenario supports the intuitive assertion that uncertainty of project outcome and CDM approval are more influential the smaller the NPV is, as seen in the global community threshold values for the *Grid* alternative in Table 5.9.

It has to be admitted that, in applying the method of expected payoffs at the investor level of analysis, risk enter into the investor NPV calculation twice, as α^t, the investor discount factor, already includes a risk premium, as discussed in the literature section. As such the method of expected payoffs are most correctly applied to the other players – the host country, the Annex 1 country, and the global community – as these players use the standard CBA method, where no risk premium is entered into the discount rate. However, the explicit modeling of CDM-related risks at the investor level allows for a specific treatment of it at this level as well, through e.g. the use of threshold values and decision rules, as done here, and through sensitivity analysis of the direct effects of p and q. The added value this approach gives to the decision process, should make it a strong candidate for inclusion in the investor NPV calculation. The risk of “double discounting” of uncertainty can be reduced or removed by adjusting the risk premium component of α^t instead[40].

6.7. Policy options

To sum up the situation as described in the discussion section so far, it states that: the *No grid* alternative is the only real option to realize the solar PV project in Indonesia; the investor profitability is too low in the base scenario to justify investment; host country project profitability is fragile in all project alternatives; Annex 1 country is the big winner payoff-wise when we move towards the likely scenario of *Low cost PV*. Given this situation, the main available policy venue available seems to be that the host country and the Annex 1 country[41] – for the remainder of this section referred to collectively as “the paying players” – share some of their net benefits with the investor, through some sort of transfers in addition to the CER-revenues generated by CDM participation. However, going down this route, two troublesome issues arise. First, such a transfer arrangement may create perverse incentives on the part of the investor. Second, the prospect of joint payments to the investor creates incentives to free-ride among the paying players – incentives that can quickly give rise to strategic behavior.

As far as the incentives for the investor are concerned, the transfers from the other players to the investor can in some sense be likened to a side payments scheme[42].And side payments are not without their pitfalls. Two main objections raised against the use of side payments, as formulated in Folmer et al. (1998), are: that the anticipation of future side payments may induce countries to minimize their own spending in order to increase the size of the anticipated future side payments; and that the parties which use side payments as a solution in one game setting, weaken their bargaining position in future games, as they create expectations that they might use side payments in to solve other negotiation problems as well. Translated to the situation at hand there is a real risk that the investor abandons low cost strategies, as costs will be covered by a third party. Moreover, given asymmetric information,

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[40] This is in fact done in the *Decision rule showcase scenario*, see section 5.3.

[41] Although the global community is also a winner in both the base scenario and in the *Low cost PV* scenario, the global community is not included as part of the “paying players” in the below discussions. This is due to the fact that the global community is in essence modeled as a composite of the three other players, and so the global community is not *per se* an individual player capable of making its own payments to the investor.

[42] Financial side payments are defined in the following way in Folmer et al. (1993, p 314): “countries who would receive positive net benefits if the agreement is concluded may provide incentives in the form of financial side payments to those whose net benefit would otherwise be negative”.

the investor has incentives to exaggerate the costs and under-communicate the revenues reported to the other players, as this as well will increase the transfers from the other players to the investor. Finally, investors, *plural*, might infer from any transfers made in relation to the CDM game, that it is possible and even easy to elicit transfers from the paying players in similar settings. This could potentially lead to a general landslide in perverse incentives for investors, and potential major headaches as far as the CDM and similar initiatives are concerned.

The above incentive issues regarding the investor are less severe than they might look at first glance. This becomes evident when one considers the main differences between a country-to-country relationship and a country-to-investor relationship. The differences can be summed up as follows: given some level of competitiveness in the industry represented by the investor, the investor and her or his firm is a replaceable entity in negotiations, whereas a country has a monopoly on its own emission reductions[43].This difference in bargaining power between a country and an investor explains and frames nicely why country-to-country relationships take the form of a negotiation situation between two equal parties[44], while the relationship between the investor and any one of the paying players is characterized as a more straight forward principal-agent relationship. If the paying players seize the role of principal, the problems related to investor incentives can be solved quite easily by employing two measures: tying the transfers to performance, and decoupling the calculation of transfer size from any parameters that are within the investor's possibility to influence (i.e. don't base payments on reported investor costs). A reasonable form that the transfers could take is this: A transfer tied directly to the number of kilowatt hours delivered by the solar PV plant (e.g. a subsidy per kWh)[45], with the size of the transfers determined by the average costs per kWh of some benchmark best-practice solar PV plant. This type of policy has in fact already been put in place in Indonesia when it comes to small-scale hydro power (Tumiwa 2011).

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[43] This is especially true of the problems that are usually available for solution through side-payments, such as acid rain problems, etc., where pollution is not uniformly mixed, and therefore pollution source matters. And although GHGs *are* uniformly mixed, the scale of the climate change issue demands collective action, meaning that the mitigation-actions of each and every country (especially the large emitters) are to some extent irreplaceable. And this situation with irreplaceable contributions gives rise to a degree of bargaining power.

[44] It might also be tempting to view the sovereignty of states as another factor, but the fact is that in the terms of economical models, an agent in the principal-agent framework is just as sovereign and unruly as any nation state.

[45] In a grid-connected situation the perfect tool would simply be an increased feed-in tariff for PV, as done in e.g. Germany (Frondel et al. 2010), but in the relevant alternative, the *No grid* alternative, the concept of a "feed-in" tariff are slightly misplaced, as one does not feed the produced power into any grid.

Leaving the investor issues behind for a moment, I now turn to the other main area of potential trouble for the policy option of separate non-CDM transfers to the investor: conflict of interests between the paying players. These conflicts are not based upon disagreement on the desired outcome[46], but rather originate from the perceived zero-sum game concerning how much of their profits each of the paying players should transfer to the investor. In this game, each paying player has strong incentives to free-ride to the greatest degree possible on the payments of the other two paying players, in order to maximize own net payoff from the solar PV project.

The free-rider incentives threaten the credibility of the paying players' commitment to make transfers to the investor. The threat of bluffed commitment is especially severe when it comes to the host country, due to two factors: first, the host country does not bear any of the investment costs related to the construction of the solar PV plant; and second, due to the fact that transfers to the investor should be linked to the price of electricity, actual transfer payments will be preceded by an investment in infrastructure by the investor. These two factors in combination could give the host country an incentive to bluff commitment to transfer payments, with every plan not to make any payments, in order to buy the solar PV plant and related infrastructure cheaply when the investor goes bankrupt in the absence of transfers. However, given the solar PV modules themselves are somewhat mobile, the risk for the investor when it comes to having to abandon her or his infrastructure investment in the case of bankruptcy of the project are smaller than when investing, say, in something like an hydro power dam, which is highly immobile once constructed.

Though the impasse created by the differences in incentives between the paying players, as outlined above, seems insurmountable at first glance, there might exist opportunities for designing some mechanism or set of agreements that circumvent the pitfalls. But there are no easy, standard plug-in solutions available, and to derive satisfactory solutions to the problems is outside the scope of this thesis. To give a hint at possible solutions, I turn to the paper by Janssen (1999), which has some interesting ideas to offer. Although Janssen (ibid) strictly speaking deals with a separate issue from the one at hand here, namely the enforcement of JI and CDM contracts, the issue discussed by Janssen (ibid) have great similarities to the issue

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[46] Although the host country strictly would prefer the *Grid* alternative, it is assumed that given that the actual alternative to the *No grid* alternative is zero investment, the host country has every incentive to back the *No grid* alternative.

described above. Janssen (ibid) discusses the trouble of enforcing commitment on the part of the host country, given that a “project sponsor” wishes to transfer money in order to make the host country undertake some abatement action that entail some level of cost for the host country. In essence, this is the same setup as the one I have described above for transfers to the investor; the Annex 1 country wishes to transfer money to the project, given that the host country also commits to bearing a cost related to the project[47]. Janssen’s prescribed solutions are: each party gives their national environmental agencies the power to punish themselves for breaching the agreement with the other parties; the host commits to honoring their part of the agreement by “strategic delegation”, i.e., entrusting an agent with the responsibility to fulfill the agreement on behalf of the host, and bind the agent by creating a contract that ensures that the agent has nothing to gain from non-cooperative behavior. Although these solutions are not necessarily a one-to-one fit with the realities of the incentive problems in the transfer scheme, they at least indicate that the problems might be solvable, partly because the alternative to cooperation is zero profits. Hence, both the host country and the Annex 1 country have incentives to at least try to resolve the problem.

This nearly concludes the discussion on policy options, and a quick summary is in order:

- A policy option where the Annex 1 country and the host country cooperate and make transfers to the investor outside the CDM mechanism seems like the only possible venue for ensuring investor profitability in the short run.
- If the transfer scheme is poorly designed, it can create perverse incentives for the investor, but this problem can be avoided with a well designed scheme.
- A well designed transfer scheme links transfer payments directly to the number of kilowatt hours of power generated by the investor, and use benchmarks outside the investor’s influence in order to decide the size of the transfers.
- When it comes to making the transfer payments, both the Annex 1 country and the host country has incentives to free-ride on the other player.
- Results found by Janssen (1999) indicate that the free-riding issues might be solvable.

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[47] The only difference is the fact that the host country does not actually perform the abatement actions in my setup, as the host country instead transfers money to the investor. Thus, the costs incurred by the host country in my setup do not equal the full abatement costs associated with the project. But this fact does not alter the applicability of the solutions prescribed by Janssen (1999).

With all this said, the elephant in the room with regards to the above discussion is: what if the project plain and simple is not viable, due to the multilevel complications involved? As discussed in section 6.2, the project profitability section, the Annex 1 country profits and the host country profits in the *No grid* alternative are both fragile with respect to the parameter assumptions. Hence, the players will both need to keep a close watch on their profitability when commitment to any transfer scheme is decided.

7. Summary and concluding remarks

This section concludes the thesis, with brief answers to the research questions posed in the introduction, followed by a hint at need for further research and a short review of the lessons learned through the process of writing this thesis.

This thesis has investigated the micro-level incentives in the Clean development mechanism by looking at the case of possible investments in a 10 megawatt peak solar photovoltaic electricity plant in Indonesia. Two main methods has been employed: applying a rough cost-benefit analysis quantification to three different project alternatives; and using decision analysis on the elements from the cost-benefit analysis. Of these two approaches, the rough cost-benefit analysis provided the most tangible results, as the decision analysis results could not be used to full effect due to lack of available data. The cost-benefit analysis finds results that are consistent with existing literature, namely that: the profitability of solar photovoltaic electricity generation to an investor is more dependent on electricity prices obtained and the costs of solar photovoltaic modules than on Clean development mechanism funding; investment in solar photovoltaic electricity generation is generally not profitable to an investor as of today; the Clean development mechanism does not provide sufficient funding for renewable energy technologies; renewable energy technologies can exhibit considerable (non-market) sustainable development benefits.

The main new contribution added to the field by this thesis is the insights regarding the aligning of the incentives of the different players involved in the Clean development mechanism. The fact uncovered is that the different incentives do not necessarily line up nicely in practice. In addition to this, a method for modeling risks encountered in the Clean development mechanism has been introduced, and the effect of risk on project profitability has been cursory examined.

Below, answers to research questions are presented in section 7.1, while section 7.2 gives ideas for further research, and section 7.3 concludes the with a few thoughts on the lessons learned while working on the thesis.

7.1. Answers to research questions

RQ1: When does investment in a typical small-scale solar PV-power plant in Indonesia yield profitability

a. *from a foreign investors perspective?*

The short answer: It will not yield profitability. Period. At least not with today's prices of PV modules, and today's level of TCs both in the CDM and in Indonesia. However, under best case conditions, investment in a standalone type project outside the CDM becomes profitable, due to a high willingness to pay for electricity in rural areas. This willingness to pay, however, might be difficult to translate to cash in on in practice. Standalone capture in cooperation with industry users in remote areas might be an alternative.

b. *from an Indonesian perspective?*

The investment is profitable from an Indonesian perspective when the feed-in tariffs or end-user payments made to the investor are low enough. In this thesis, replacing grid electricity or electricity from diesel generators are both shown to be profitable for the host country, as are using a solar PV plant in standalone mode to deliver power to off-grid villages. However, these results are very sensitive to increases in electricity prices.

c. *from an Annex 1 country's perspective?*

The only profitable project alternative analyzed for the Annex 1 country is the alternative where the solar PV plant is used outside the CDM and outside the state-owned grids. The main cause for this is, just as for the investor, the fact that rural willingness to pay for electricity is much higher than the in-grid prices, as the in-grid prices are kept artificially low through max price regulations in Indonesia. These max price regulations make it impossible for solar PV generated electricity to compete on price and recover costs at the same time.

d. *from a global perspective?*

The same is true for the global community as for the Annex 1 country; only the standalone power generation option is seen as profitable under the standard assumptions used in the analysis. However, the drivers behind the global community conclusions are the host country benefits, not the electricity prices.

RQ2: Which parameters are most influential on the results in RQ1?

The most influential variables on the profitability results are summarized in

Table 6.1 in the discussion section. The price of electricity is influential on all the players except the global community, while non-market sustainable development effects are the most influential positive effect as far as the global community is concerned. Further, the solar PV module costs are influential on all the players except the host country.

RQ3: Given the results in RQ1 and RQ2, are there any obvious conflicts of interest between players?

Yes, there are. Most notably, there is opposing interests when it comes to the size of the electricity prices; while the investor and the Annex 1 country profit from high electricity prices, the host country profit from low electricity prices. This observation might seem trivial, but coupled with the fact that electricity prices are the most influential factors in determining project profitability for all the three players involved in this conflict, testament to the seriousness of the issue. The additional CER-revenues that are supposed to create a win-win situation for the CDM players are simply not sizable enough relative to the other costs and benefits that make up project profitability. And thus the CER-revenues lose their ability to untangle the underlying conflicts of interest.

RQ4: To what extent do the cash flows related to the Clean Development Mechanism (CDM) influence the results in RQ1?

The short answer is: To a very little extent. Solar PV technology is too unprofitable with the current electricity prices in Indonesia and the current module prices that CDM money make any drastic differences.

RQ5: How does uncertainty regarding project outcome and CDM approval affect the payoffs of the four different players?

Uncertainty, both regarding project outcome and regarding CDM approval, seems to have little effect on the player decisions to commit in the project studied here, due to the size of the overall project payoff relative to the size of the transaction costs that are incurred with certainty at project startup. However, indications from some of the quantitative results point towards the fact that uncertainties could have decisive impacts on the marginally profitable projects. Further, simple graphical results indicate that the “discounting effect” from uncertainty on expected project payoff might prove to be substantial, but due to lack of available data, this was not investigated in depth.

RQ6: Given the conclusions in the above questions, which policy instruments may be used to correct for any discrepancies between the different levels of analysis?

The main discrepancy that has to be dealt with in order to make a project feasible is the fact that the investor does not find any of the project alternatives viable. The main policy instrument stands out when it comes to dealing with this is: A transfer scheme where the other players cooperate in transferring parts of their payoffs to the investor in order to induce project profitability for the investor as well as themselves. This policy is not feasible in the base scenario, but could yield positive results in a scenario where the price of solar PV modules drops sharply.

7.2. Further research

This walkthrough on the micro-level incentives in the CDM has been rather non-technical in its assumptions compared e.g. to the game theoretical literature on international climate negotiations. A possible venue for future research would be to take the framework presented here and give it a more rigorous fundament, using appropriate functional forms for the different main effects, instead of grouping them together in an aggregate NPV. This could ensure getting even more general results than the ones derived here.

Developing a more sophisticated model for project failure[48], including the possibility of explicitly modeling in strategic behavior from the players, also looks like a promising venue. This could include allowing for endogenous determination of p, the probability of project success (as determined by the host), and/or q, the probability of CDM approval.

It might also be possible to study Indonesia as a case further, replacing the rather coarse assumptions used in this thesis with more detailed assumptions and fine-tuned estimates.

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[48] Prime examples of parameters that it would be interesting to model with greater sophistication are: The time at which failure occurs, the type of costs incurred when failure occurs and the magnitude of the costs incurred. Any and all of these could probably be modeled as stochastic variables.

Further, the method used in this thesis might be applied to other technologies and host nations, and possibly specific Annex 1 nations as well, in order to investigate how the general results found here transfer to other cases.

7.3. Lessons learned

Thesis writing is, I suspect, as much as anything a learning experience. Valuable lessons regarding my own writing and regarding project planning and execution has dawned on me during the hectic four months spent writing this thesis. On the positive side, my theory that posing the right questions early is key got confirmed. On the negative side, I have learned the hard way that data collection, inspection and preliminary quantification cannot be done early enough. In my case I focused too hard on the theoretical foundations of the thesis in the early stages of writing, and thus finished data collection too late, and as a result I realized too late which variables were possible to quantify and which were not. Especially, the lack of available estimates for p and q has hampered the possible usages of the decision analysis results, and with too little time in the end to adapt my methods to the available data, the ideas on decision analysis are not followed through to their maximum potential. Nevertheless, it is both my hope and my belief that my contribution to the CDM-literature and the *Small is beautiful?*-project, humble though it may be, can bring about an increased interest in micro-level investigations of the CDM, and the application of either decision analysis or game theory to the CDM as an arena of research.

8. References

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9. Appendixes

9.1. List of interview subjects

NAME	TITLE	INSTITUTION	DATE AND PLACE
Dr. Terry Lacey	Independent Journalist and advisor	*Jakarta Post etc.*	March 28th. 2011, Jakarta
Drs. R. M Sodejono Respati	Chairman	*Solar Energy Focus Group, Indonesian Renwable Energy Society*	March 28th. 2011, Jakarta
Fabby Tumiwa	Executive Director	*Institute for Essential Services Reform (IESR)*	March 29th. And 31the, Jakarta
Eivind S. Homme	Ambassador	*Royal Norwegian Embassy, Jakarta*	March 29th. 2011, Jakarta
Constantin N. Karame	First Secretary		
Dr. Irhan Febijanto	Ass. Deputy and RE-Researcher	*Badan Penkajian Dan Penerapan Teknologi (BPPT)*	March 29th. 2011, Jakarta
Agus Sari	President Commissioner, Non-Executive Director	*Iklimkarbon*	March 29th. 2011, Jakarta
Hari Yuwono	Project Development Officer	*Private Financing Advisory Network, CTI, PFAN (The World Bank Group)*	March 30th. 2011, Jakarta
Anders Cajus Pedersen	Advisor	*Mini-hydro Power Project for Capacity Development (MHPP), Deutche Gesellschaft für*	March 30th. 2011, Jakarta

		Internationale Zusammarbeit (GIZ)	
Timothy H. Brown	Natural Resource Management Specialist	*The World Bank*	March 31th. 2011, Jakarta
Ishmid Hadad	Chairman	*The Working Group on Financial Mechanisms – National Council on Climate Change*	March 31th. 2011, Jakarta
Arnfinn Jacobsen	Technical Adviser	*IndoPacific Edelman*	March 31th. 2011, Jakarta

9.2. Null and project alternatives in detail

Below clear definitions of the null alternative and the investment alternative are provided for all placement alternatives at both the global and the Annex 1 country level. The investor level alternatives are handled only briefly. The reason for this is that there is a great difference in the complexity of the task of finding effects when using accounting costs and revenues, as is done at the investor level of analysis, and when using social costs and benefits, as is done at the global and national levels of analysis. In the former, the null alternative simply is no investment at all, and then all cash flows accruing to the firm are used in the NPV analysis. In the latter, the null alternative has to be carefully defined in order to determine the size and sign of the project effects compared to business as usual.

In all of the investment alternatives, it is assumed that the PV power project does not lead to an increased demand for electricity as compared to the null alternative. This is due to two factors incorporated into the null alternative. The first of these factors is the massive subsidies currently made by the government to power consumers, resulting in a considerable excess demand already. IEA bluntly states in its report "Energy Policy Review of Indonesia" that in 2008 an estimated unserved demand existed that would immediately consume an additional 4000 MW of installed capacity, if it was offered (IEA & OECD 2008, p 179). Further, an annual growth rate of 7% during the time span 1997-2004 is estimated in the same report (IEA & OECD 2008, p 177). The second factor is the ambitious electrification targets of the GOI and PT PLN stated in various official documents (see e.g. …) and verified by several independent reports (see e.g. IEA & OECD (2008) and Leitman (2009)). The main targets involved is the GOI target of an electrification rate of 93% by 2020 and the PT PLN target of an electrification rate of 100% by the same year (Leitman 2009, p 179). These targets will, if met, contribute to an increase in consumed electricity in the null alternative during the project lifetime.

9.2.1. Global level alternatives

Due to the use of three different scenarios, one null alternative has to be created for each scenario. Each of the null alternatives is meant to represent one facet of the same reality, as the business as usual scenario naturally will be different for each of the types of environments described by the different scenarios. Below, the main characteristics of and differences between the scenarios are discussed, and then a summary table of the effects is provided.

It is assumed in all scenarios that investment in PV solar power in Indonesia will not occur in the null alternative. Thus, some benefits relating to learning-by-doing effects, if they are applicable (see the literature section for a discussion), might be attributed to the investment project alternatives across all scenarios.

Further, it is assumed that there is a degree of slack in the Indonesian economy in the form of unemployment in the null alternative, and hence any hiring of local hands in the investment alternative will bring benefits by way of reduced unemployment. This seems to be a reasonable assumption, given that Indonesia in recent times has had a much higher unemployment rates than other Southeast Asian developing economies, such as Thailand and Malaysia (Suryadarma et al. 2007), and in 2003 the official unemployment rate was 9.5% (ibid, p 4).

Regarding other common factors, it is assumed that in the null alternative investor money is put to rewarding use elsewhere in the economy, and that the time of CDM staff and DOEs are fruitfully spent elsewhere in the absence of the project, and that this productive use of the time of the staff would be displaced by investing time in approving the Indonesian PV project. Further, it is assumed that the land used for the PV power plant in the investment alternative has some other productive use in the absence of investment. In the investment alternative, it is assumed that the investors will have to rent the land, and that this income offsets the opportunity costs of landowners foregoing the land (thus the only cost related to the land that shows up uncountered are the OC of the land rent expenses incurred by the investors, as part of their investment costs).

The grid scenario: In the grid scenario, a null alternative of considerable investment in additional power to the grid on the part of Indonesia during the project life time is assumed. This is seen as reasonable on the background of reports issued by both the World Bank and the IEA (see IEA & OECD (2008) and Leitman (2009)). The IEA deduces an average rate of growth in power capacity in Indonesia of 4.4% in the 1997-2004 period (IEA & OECD 2008, p 177). Further, we assume that the ambitious levels of electrification by the year 2020 cited above are met.

The replace diesel alternative: The null alternative in the diesel scenario assumes zero indonesian investment in capacity and transmission in the target villages in the diesel scenario. The logic behind this assumption is that the GOI and PT PLN will prioritize villages without over villages that are already self-supplying through diesel generated power, in order to meet the goals of complete electrification by 2020 on schedule. Reasoning along the same lines, it is assumed that no significant investments in infrastructure and capacity building will be made in the decade beyond the 2020 push, as the GOI has substantial budget deficits and has under-spent in every area of public sector other than electricity since the early 2000s (WB 2005).

The no grid alternative: From the reasoning in the above paragraph, it is assumed that the GOI and PT PLN will invest in electrification of the off-grid villages in the null alternative of this scenario. The question of when is another matter – it could be as late as in 2020, almost halfway through the project lifetime.

Therefore, when it comes to reduced GHG emissions in the investment alternative in this scenario, two baselines are used. This is due to the fact that electrification of the villages in the null alternative will occur sometime during the project lifetime. Before this point a pre-electrification baseline is used, and after this point, the grid energy mix is used for the baseline. For quantification of these baselines, consult the data section of the thesis.

Scenario	The null alternative	The investment alternative
Grid	Indonesian power investment CDM-staff time used on other projects BAU emissions of GHG from electricity generation Unemployment in the Indonesian economy	*Costs:* OC of invested capital OC of CDM-staff time SCC of any non-additional CERs awarded *Benefits:* Cheaper GHG abatement Learning-by-doing effects for solar PV by deployment in Indonesia

		Reduced need for Indonesian investment in power capacity Reduced unemployment in Indonesia (*)
Diesel	No Indonesian power investment CDM-staff time used on other projects BAU emissions of GHG from electricity generation Unemployment in the Indonesian economy Local air pollution from diesel power plants	*Costs:* OC of invested capital OC of CDM-staff time SCC of any non-additional CERs awarded *Benefits:* Cheaper GHG abatement Learning-by-doing effects for solar PV by deployment in Indonesia Reduced unemployment in Indonesia (*) Better local air quality
No grid	Indonesian power investment CDM-staff time used on other projects BAU emissions of GHG from electricity generation Unemployment in the Indonesian economy	*Costs:* OC of invested capital OC of CDM-staff time SCC of any non-additional CERs awarded *Benefits:* Cheaper GHG abatement Learning-by-doing effects for solar PV by deployment in Indonesia Reduced need for Indonesian investment in power capacity and transmission Reduced unemployment in Indonesia (*) Benefits of earlier electrification (up to 10 years earlier than in BAU) (*)

The global perspective - Summarized main assumptions of the null alternative and the investment alternative. (*): Effect is not quantified in the NPV analysis.

9.2.2: National level alternatives

The null alternative is the same for each of the scenarios as in the global level analysis, but due to the fact that only Indonesian citizens have standing, some effects in the investment alternative drop out, or change sign or change magnitude between the two levels of analysis. Also, some of effects concerned as "money changing hands" in the bigger picture of the global level analysis, appear here as costs or benefits, as we are now looking at the small picture, and money going in or out are treated as benefits or costs accordingly.

One of the main differences is that all costs pertaining to the international investors and to the CDM-staff are disregarded, due to the fact of lack of standing. Also, the SDR is different than the global SDR, but this is treated in the data section of the thesis.

As for power payments, payments made by PT PLN to the foreign investors through feed-in tariffs are treated as costs (these can be viewed as the "leasing costs" of buying power from the PV power plant instead of building a power plant of their own). Payments made by end-users are treated as costs in the investment alternative as well, as the benefits of the payments are assumed to accrue to individuals without standing (the foreign investors, that is).

The impact of reduced GHG emissions might also different from the impact used in the analysis at the global level. They might be somewhat lessened, due to the likely environmental preferences of the Indonesian people, given by the effects as described by the environmental Kuznets curve (EKC) literature, but then again, Indonesia are also somewhat likely to feel the effects of climate change more strongly than the average country. The compounding of these two effects lead to uncertainty about the end result. For simplicity's sake, the Indonesian valuation of the SCC is assumed to be identical to the global evaluation.

A note has to be made about taxes and bribes. Taxes and bribes often appear to be two sides of the same coin in Indonesia. Both these entities are grouped together here, and the overall flow is assumed to increase relative to the null alternative with the presence of more international investors.

Scenario	**The null alternative**	**The investment alternative**
Grid	Indonesian power investment Local DNA-staff time used on other projects BAU emissions of GHG from electricity generation Unemployment in the Indonesian economy Normal tax level	*Costs:* Feed-in tariff payments for power supplied OC of DNA-staff time *Benefits:* Reduced damage from GHG emissions (national valuation) Reduced need for Indonesian investment in power capacity Reduced unemployment (*) Increased tax revenue
Diesel	No Indonesian power investment Local DNA-staff time used on other projects BAU emissions of GHG from electricity generation Unemployment in the Indonesian economy Normal tax level	*Costs:* End-user payments for power supplied OC of DNA-staff time *Benefits:* Reduced damage from GHG emissions (national valuation) Reduced unemployment (*) Better local air quality Increased tax revenue
No grid	Indonesian power investment Local DNA-staff time used on other projects BAU emissions of GHG from electricity generation Unemployment in the Indonesian economy Normal tax level	*Costs:* End-user payments for power supplied OC of DNA-staff time *Benefits:* Reduced damage from GHG emissions (national valuation) Reduced need for Indonesian investment

		in power capacity and transmission Reduced unemployment (*) Benefits of earlier electrification (up to 10 years earlier than in BAU) (*) Increased tax revenue

The national perspective - Summarized main assumptions of the null alternative and the investment alternative. (*): Effect not quantified in the NPV analysis.

9.2.3. Investor level alternatives

The null alternative is the same across all scenarios at the investor level; no investment. The null alternative will therefore not be discussed further at this level of analysis.

Attention is instead given to the differences in costs and benefits between the different scenarios. The differences are summarized in the table below. As mentioned before, the costs and benefits on this level of analysis translates to the flows of accounting costs and revenues accruing to an imagined investor firm that is owner of the PV power plant project.

The differences between the scenarios are minimal. In the grid scenario, the power is sold to PT PLN, and payments are regulated by feed-in tariffs, and only a short transmission line to ensure grid hook-up is needed.

The diesel scenario on the other hand, deals with power sold to end-users, for a price equal to that of the diesel generator price per kWh. Distribution lines are present, as all households in each village is assumed to be connected to a distribution network that receives power from the local diesel generator plant (REF). However, transmission lines to the different villages have to be constructed.

As for the no grid scenario, the cost side here closely matches the cost side in the diesel scenario, but with the additional need to build distribution lines from scratch as well. Also, on the revenue side both the CDM payments and the end-user payments could well be markedly different from the diesel scenario. The former because of the baseline switch discussed in the global level subchapter, and the latter because the WTP for electricity of households without access to a diesel generator might prove to be very different from the WTP for electricity of households hooked up to a diesel generator.

Note that in both the diesel scenario and the no grid scenario, an assumption of zero installed battery capacity from the investing firm is made. Local villagers are assumed to invest in batteries in their own homes and save up needed electricity for the night during day time. This assumption is mainly done as no firm in its right mind would consider investing in the amount of battery capacity needed to supply the locals with the kind of power they need. A hybrid solution with hydro or gas alongside PV might be a viable alternative, but for simplicity the details around a hybrid solution is not considered in the analysis in this thesis. If you consider a hybrid solution of 10 MW peak, then you will probably be able to invest in the other part of the hybrid as cheap or cheaper than PV per MW peak.

The grid alternative	**The replace diesel altnernative**	**The no grid alternative**
Costs: Operating costs Plant building costs Transmission line building costs CDM related costs Other investment costs *Revenues:* CDM-payments Scrap value sale of plant Feed-in tariff payments	*Costs:* Operating costs Plant building costs Transmission line building costs Distribution line building costs CDM related costs Other investment costs *Revenues:* CDM-payments Scrap value sale of plant End-user payments	*Costs:* Operating costs Plant building costs Transmission line building costs Distribution line building costs CDM related costs Other investment costs *Revenues:* CDM-payments Scrap value sale of plant End-user payments

The investor perspective – Costs and revenues in the different scenarios. (*): Effect not quantified in the NPV analysis.

9.3: Detailed overview of data used

This appendix provides an overview of all the data used for quantification in this thesis, with appropriate references. Explanations of the estimates are given when it is needed.

9.3.1. Technical NPV related

Discount rates

Parameter	**Estimate**	**Source**
r, risk free interest rate	3.71%	OB (2011)
z, risk premium Indonesian projects	12%	Anger et al. (2007, p 506)
δ_1, the SDR for Indonesia	10.6%	Kula (2004, p 97) OECD (2011a)
δ_2, the SDR for Annex 1 countries	3%	Evans (2006, p 11)
δ_3, the SDR for the gobal community		

Discount rates.

For a due note on methods of calculation of the SDR and the private discount rate, consult the methodology section.

As the discount rate of the private investor is made up of the risk free interest rate plus a risk premium, hence, the discount rate here is 15.71%. The risk premium given here is a measure for South-East Asia excluding India (Anger et al. 2007, p 506). The risk free interest rate for a given period is defined as the "interest rate at which money can be borrowed or lent without risk over that period" (Berk & DeMarzo 2007, p 52). Here, the risk free interest rate is set equal to the market yield on 10 year Norwegian government bonds is used.

The SDR for Indonesia is based on the η and ρ for India, of 1.64 and 0.013 respectively, estimated by Kula (2004, p 97). These estimates are combined with an estimate of the economic growth in Indonesia in order to calculate the SDR through the Ramsey rule. OECD (2011a) estimates the real economic growth for Indonesian in 2007 to be 6.3 %, rising from

5.5% in 2006 and lower growth the previous six years. Given these figures, and an ambitious pro-growth policy on behalf of Indonesia (Hadad 2011), the estimate of 6.3% is viewed as appropriate and even conservative. These estimates put together give the estimate for the SDR found in table X above.

The SDR for Annex 1 countries are based on an estimated benchmark SDR for the EU countries done by Evans (2006), where he uses empiric estimates for the different parameters in the Ramsey rule to derive the final SDR. This means the generic Annex 1 country in this thesis is loosely based on the EU. This is seen as a reasonable approach, as the EU is currently the main buyer of CERs in the market (Kossoy & Ambrosi 2010).

The same SDR is also used as the SDR for the global community. This is seen as reasonable given the method used by Evans (2006), as there seems to be some agreement on the use of the Ramsey rule to derive the SDR (see section 2.2). Further, Stern (2008) estimates on ethical grounds that the SDR should fall in the range of 1.5-5%, and although this stance is somewhat controversial, the fact that the two estimates confirm each other adds another layer of security to the use of 3% as an estimate.

9.3.2. Solar PV plant related and other technical

Plant electricity generation potential

Variable	Estimate	Source
Solar potential in Indonesia	4.8 kWh/m2/day (1752 kWh/m2/year)	IEA and OECD (2008, p 92)

Electricity production potential

Variable	Estimate
Size of a typical solar PV panel	1,5 m2
Effect of a typical solar PV panel	240 Wp
Number of effective hours per year	1500 hours/year
Technical loss in the plant system	25% of yearly

	production
Electrical efficiency of modules	15%
Degradation in electrical efficiency per year	0,5%

The basic characteristics of a solar PV plant. Source: Albert (2011).

The yearly degradation in electrical efficiency is deemed negligible (efficiency will only be reduced with about 10% during the project lifetime), and thus not incorporated into the NPV-models. For calculation purposes, 350 operative days per year are assumed.

Plant investment costs

Variable	**Estimate**	**Source**
Module costs	3.19 USD/Wp	Solarbuzz (2011)
Inverter costs	0.715 USD/continuos watt	Solarbuzz (2011)
Battery costs	0.212 USD/output Wh	Solarbuzz (2011)
Charge controller costs	5.93 USD/Amp	Solarbuzz (2011)

Table: Plant infrastructure related investment costs. Source: Solarbuzz (2011).

All component prices are March 2011 prices.

Variable	**Estimate**	**Source**
Transport and documentation	5 % of total investment	Albert (2011)
Rigging and testing	25 % of total investment	Albert (2011)
Yearly operation costs	10 % of yearly revenue	Albert (2011)

Table: Investment and operation related costs.

The transport and documentation costs and the rigging are estimated as 5% and the rigging and testing costs as 25% of the total investment cost respectively. This based on a rule of thumb applicable when one orders a solar project as a turnkey project from a single producer rigged for on-grid production, i.e. without any battery capacity. The estimates are taken from Albert (2011), who is a Project Manager in Renewables at Statkraft.

It is worth noting that the percentage relationships given above are valid under today's PV module prices. Declining module costs will probably heighten the share of the total investment amount allotted to other costs than the module costs. To take this into account, USD amounts based on current module prices and the above percentages were put into the NPV model, not the above percentages. This means that in simulations the transport, documentation, rigging and testing costs will not be dependent on the module costs. E.g. in a simulation where module costs are decreased dramatically, the relative component of the total invested amount coming from the other costs mentioned will increase.

The yearly operation costs are based on the assumption that all operation is contracted away to the supplier of the plant. This estimate and method is based on Albert (2011). The percentage was put directly into the NPV model, making the operation costs a variable cost, increasing with increasing revenues. This is seen as a reasonable assumption, although if the investing firm is in a strong bargaining position, it may be able to secure a more favorable contract where operation costs are kept fixed.

Life time and horizon value of the plant

The lifetime of a solar PV plant running full time is normally around 20-25 years, after which time the PV modules must be replaced due to fatigue in the materials (Albert 2011). To account for this, the project lifetime in the analysis is set at 21 years. At the end of the project life time, the horizon value is set to zero.

9.3.3. Carbon and CDM related

Variable	Estimate	Source
Average CER price 2009	16.6 USD/tCOe	(Kossoy & Ambrosi 2010, p 14)
The Social Cost of Carbon (SCC)	23 USD/ton carbon (6.277 USD/tCO2e)	(Tol 2008, p 10)

Various carbon related estimates

The SCC is taken from the meta-study by Tol (Tol 2008), more specifically his estimate included a risk premium to account for the considerable risks inherent in climate change damages. The SCC is converted to a price per ton of CO2-equivalent through computing the relative mass of carbon present in CO2[49] estimating the same fraction of the SCC.

Baselines

Variable	**Estimate**	**Source**
Grid baseline	0.754 tCO2e/MWh	Sungkar (2010)
Diesel generator baseline	0.779 tCO2e/MWh	See table X below.

Baselines of electricity generation

Note that the PDD referred to in the above table is approved and has been awarded CERs by the CDM executive board, and so the baseline can be viewed as an officially approved estimate of the grid baseline (UNFCCC 2011b). The grid in question is the JAMALI grid, serving Java, Bali and Sulavesi (Sungkar 2010).

The diesel baseline components are broken down below.

Diesel baseline calculations

	Emissions (tonnes/MWh)	**Global Warming Potential (100 year horizon)**	**CO_2-equivalent emissions (tonnes/MWh)**
CO_2	0.772	1	0.772
CH_4 (methane)	0.0000383	25	0.0009575
N_2O	0.0000219	298	0.006526

Table X: Diesel baseline calculations. Sources: Emission data from Widiyanto et al. (2003) p 655, GWP from Forster et al. (2007) p 212, and CO_2-equivalent emissions calculated through methodology found in Pachauri and Reisinger (2007) p 36.

Regarding the Global Warming Potential as a metric in climate calculations, the IPCC notes that although the GWP metric is widely debated and has its shortcomings, “GWPs remain the

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[49] The molar mass of carbon is 12.01, while the molar mass of oxygen is 16.00 (see e.g. Atkins & de Paula 2006), this equals a total molar mass of CO2 of 44.01. In other words, about 27.28% of the total mass of CO2 is made up of carbon.

recommended metric to compare future climate impacts of emissions of long-lived climate gases" (Forster et al. 2007, p 211). It should be noted, however, that the global warming impacts of the different gases are not comparable although the emissions have been standardized (ibid). But on that note, the subject is left alone for the remainder of this thesis, as the natural science behind climate change is not the main focus here.

Transaction costs of the CDM

Variable	**Estimate**	**Source**
TCs, minimum fixed CDM related	392,000 EUR (505,800 USD)	Michaelowa and Jotzo (2005, p 514)

Transaction costs

The transaction costs are typical pre-implementation transaction costs, based on pilot fase projects supported by the PCF (operated by the World Bank). (Michaelowa & Jotzo 2005)

Opportunity cost of CDM-staff time

To find the OC of CDM-staff time of seeing the solar PV plant through the CDM application process, you need to know two things: how much time the CDM-staff use and what the OC per time is (e.g. by using the average staff wage as a proxy). Both of these estimates are not known in this thesis. So, instead, some assumptions are made, in order to find an estimate for the OCs that could at least function as an illustration of the effects of the OCs related to the CDM.

According to the condition of employment the UNFCCC (2011a), the salaries of UNFCCC professional employees are determined according to the standard salary scales of the United nations. The lowest level and step of professional base salaries found in the UN is a net annual salary of USD 37,154, obtained from current UN salary scales (UN 2011). Please note that this is a minimum wage, as so-called *post adjustment*-money is always added to the base salary, in order to cover difference in living costs across countries. But as the weights for these are not readily available at the time of writing this thesis, the base salary is used as an approximate for the final salary of the UNFCCC staff.

As for the time and resources used on evaluating a single PDD, no good publicly known estimate seems to exist. In the World Bank report "State and Trends of the Carbon Market 2010", it is stated that it took the average project 607 days to move from registration status to first issuance of CERs in 2009, and 572 days to reach registration in the same year (Kossoy & Ambrosi 2010, p 42). This gives a staggering total of 1,179 days (just over three years) from PDD delivery to first issuance of CERs for the average project. Given regulatory bottlenecks and the large volume of project being submitted, a substantial time of this total is probably spent just "waiting in line". However, there appears to be no estimate publicly available on just what amount fraction of waiting time is actually used by the CDM staff to evaluate each project. An assumption therefore has to be made. Half a year is chosen as an estimate, equaling about one sixth of the total waiting time, or e.g. a team of two researchers using three months total on evaluating the project.

Variable	**Estimate**	**Source**
UNFCCC staff salary, minimum	37,154 USD/year	See above paragraph.
Total time used to evaluate project PDD	6 man-months	Own assumption.
OCs of CDM-staff, based on the above	18,570 USD	Calculation (rounded down)

OC of CDM-staff time.

9.3.4.: Annex 1 country related

Abatement costs in Europe

It is assumed that there is a surplus of demand for CERs from CDM project in the null alternative, such that in the absence of the project, Annex 1 countries has to abate an emissions amount equal to the CERs domestically.

Variable	**Estimate**	**Source**
Average price of EUAs 2009	18.7 USD/tCO2	Kossoy and Ambrosi (2010, p 5)

Price of EUA permits in the EU ETS.

As the EU is currently the main buyer of CERs (Kossoy & Ambrosi 2010), the aggregated costs of domestic abatement within the EU are compared with the price of CERs to get an estimate of the gains from trade. The average price of EUAs (European Union Allowances, the emission quotas in the EU ETS) is used as measure of the marginal abatement costs in Europe. This seems reasonable, as by the design of the trading mechanism, permit price should equal marginal abatement costs at the margin.

9.3.5. Indonesia related

Wages in Indonesia

Variable	Estimate	Source
Minimum wage of worker[50]	105.9 USD/month	World Bank (2011a)

Wage of local workers.

The minimum wage is used throughout as a very conservative estimate of the minimum costs of labor in Indonesia.

Profit tax Indonesia

For the purpose of the quantification, it is assumed that the investor sets up a firm in Indonesia that runs the solar PV project. The World Bank estimate a profit tax of 37.3% for a medium-size firm operating in Indonesia (WB 2011b, p 50), and this estimate is used here. It is assumed that this tax applies to both revenues from sales of CERs and revenues from selling electricity.

Electricity prices

Variable	Estimate	Source
PLN electricity tariff for business-users	1,100 IDR/kWh (0.121 USD/kWh)	GOI (2010)
WTP for lighting in Indoensia	0.71 USD/kWh	WB (2008, p 41)

Table. Electricity payments

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[50] The minimum wage is based on a the wage of a 19 year old worker or apprentice (WB 2011a).

The business tariff was found in a government regulation, with the help of Tumiwa (2011) for translation.

Adverse health effects of diesel generated power

Variable	**Estimate**
SO2 damage	0.0297 EUR/kWh
NOX damage	0.0919 EUR/kWh
Particle matter damage	0.0220 EUR/kWh
Sum damage	*0.1436 EUR/kWh* *(0.1852 USD/kWh)*

Table: Adverse health effects of diesel generated power. Source: Wijaya and Limmeechokchai (2010), p 85.

Indonesian power investments

Variable	**Estimate**	**Source**
Investment costs new coal power plant	1,329 USD/kW	Yang et a. (2008, p 1944)

Table: Indonesian power investments.

The investment costs are “overnight” costs, meaning cost as if the project was completed overnight, without any interest accruing on loans (Yang et al. 2008). Further, these costs are generic investment costs, not specific investment costs for Indonesia. Whether investment would be cheaper or more expensive in Indonesia is unknown.

TCs in Indonesia

Variable	**Estimates**			**Source**
	Procedures needed	*Time spent*	*Cost incurred (% of GNI per capita)*	
Getting a local limited liability company up and	9	47 days	22.3 % (570 USD)	WB (2011b, p 8)

going				
Obtaining needed permits to build a warehouse	14	160 days	173.3% (4,440 USD)	WB (2011b, p 18)
Sum	*23*	*207 days*	*195.6 %* *(5,010 USD)*	*Own calculations.*

Startup transaction costs, bribes and employee wages not included.

The estimates in the above table are by no means ideal fits for the case of constructing a solar PV plant, but they are used as proxies in order to obtain a rough estimate of TC incurred in Indonesia, in order to investigate the potential importance of such TCs in determining project profitability.

The GNI (gross national income) of Indonesia is used to compute dollar values for the variables in the above equation. The estimate for the GNI per capita is taken from ADB (2011, p 3), where it is estimated to be 23,414,000 IDR per capita in current 2009 prices. This was converted to USD through using the standard exchange rate used in the rest of this appendix, resulting in an estimated GNI per capita of 2,570 USD (rounding down).

In addition to the official costs incurred, as detailed above, the investor will need to employ someone to take care of the registration, leading to wage costs. For the purpose of estimating some basic wage costs, it is assumed that two workers are employed at the minimum wage during the entire registration projects. Rounding the 207 days up to 7 months, this gives an estimate of wage costs of 1,480 USD, rounded down. **This brings total Indonesia-related TCs up to 6,490 USD.** The costs of bribes are not included though their share of the TCs may be substantial, as no estimates were found[51].

Tax revenues

The tax revenues to the GOI are the mirror image of the official costs of business registration in the investor TC table.

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[51] Henderson and Kuncoro (2011, p 165) estimate the corruption costs to be 7% of manufacturing costs for manufacturing firms on Java, but this estimate is deemed unusable as solar PV production has no direct equivalent of manufacturing costs, blocking out the possibility of plug-in use of the estimate.

OCs to the GOI

The OCs of the GOI in the procedures above is difficult to measure. Three simplifying assumptions are used in order to produce a conservative lower bound estimate: first, the minimum wage is used as a proxy for the OC per time; second, it is assumed that only two officials are involved in the process at the time; and third, it is assumed that the GOI officials use only 50% of the time the investor does to see the project through (the rest of the time on part of the investor is assumed to be time spent in queue). From these assumptions we get the estimates below.

Variable	**Estimates**		**Source**
	Time spent	*OCs incurred*	
OCs of giving out a local limited liability company up and going	24 days	170 USD	Own calculations.
OCs of giving out needed permits to build a warehouse	80 days	565 USD	
Sum	*104 days*	*735 USD*	

OCs of business startup to the GOI.

These costs are in reality negligible in the context of the project, given the size of other costs and benefits incurred at the Indonesian level. Still, they are included in the NPV-calculations, in order to indicate the fact that the OCs are non-zero.

9.3.6. Exchange rates

These exchange rates are used to convert all estimates found in foreign currency:

Currency	**Exchange rate, average 2010**
Euro (EUR)	0.775 EUR/USD
Indonesian rupiah (IDR)	9,090.434 IDR/USD

Exchange rates. Source: OECD (2011b).

The exchange rate is yearly average rates for 2010, taken from the OECD web pages (2011b).

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