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Economic risk analysis of decentralized renewable energy infrastructures – A Monte Carlo Simulation approach

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A B S T R A C T

There are several different economic barriers such as high up-front capital costs, high transaction costs and divers risks (e.g. performance and technical, contract risks, market risks) that keep potential investors or institutional lenders from investing in decentralized renewable energy technologies (RETs). Therefore, suitable business models, specific financing concepts and advanced risk management tools to deal with issues concerning transaction costs and financial risks are required to support RET investments.

This article deals with this issue by introducing a Monte Carlo Simulation (MCS) approach to risk analysis based on an entire life-cycle representation of RET-investment projects. By doing this, the authors uncover considerable advantages regarding content and methodology compared to ordinary NPV-estimation or sensitivity analysis. It could be shown that the presented financial analysis combined with MCS aids in optimizing the conceptual design of an investment project with respect to capital returns and risk. Since both issues are decisive for lenders and investors, the double-criteria analysis method presented in this paper facilitates the raising of capital for project investments in decentralized RETs.

1. Introduction

A shift towards renewable energy sources characterizes economic and environmental policy measures in countries all over the world. Especially in the European Union (EU), ambitious goals for climate change mitigation have been set. According to this, mandatory national overall targets and measures for the use of energy from renewable sources are defined by the European Commission (Directive 2009/28/EC) to increase the share of renewable energy in the EU gross final consumption of energy to a minimum of 20% by 2020 [1].

Among other strategies pursued in most countries to reach this ambitious goal, decentralized, small scale renewable energy technologies (RETs) and the related energy production facilities, such as small scale bioenergy infrastructures, small scale wind farms and solar plants, are changing the structure and characteristics of the regional, national and even interconnected international energy supply infrastructures to an ever more rapidly growing extent. In spite of numerous benefits resulting from the implementation of RETs, e.g. their contribution to environmental protection, their impacts on economic growth by creating jobs, by forming human capital and by offering a market for new business models, several technical and economic barriers delay the implementation of RETs. Among these, financial obstacles play a particular role [2–5].

First of all, RETs usually come with higher power-specific up-front capital costs than investments into conventional energy infrastructures. Furthermore, high transaction costs and other risks (e.g. performance and technical risks of the used technical facilities, contract risks with the suppliers of raw materials such as bioenergy crops, market risks such as future price developments and the impact of demographic changes to the local demand of energy) may hinder potential investors or institutional lenders to invest in RETs [6,7].

In general, capital costs are a function of the borrower's credit rating, the provided securities, the leverage ratio, and the aggregated project risk. Usually, higher aggregated project risk leads to higher interest rates requested for the loan or even to the complete loan denial by lenders such as banks. The spread of interest rates for

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higher risk investments is one of the direct consequences of the Second and Third Basel Accords of the international regulatory system for banking. Equity investors and institutional lenders link their return on investment (ROI)-expectations with project inherent risk. Thus, as in other domains of asset-financing, risk assessment and risk management are crucial prerequisites for financial feasibility of renewable energy projects.

Therefore, coping with financial constraints of renewable energy technology (RET)-investments requires a stable and reliable political and legal framework so potential investors can reduce regulatory risks and hence significantly reduce the cost of capital [8]. Moreover, suitable business models, specific financing concepts and advanced risk management to deal with transaction cost and financial risk issues [9] are required to support RET investments under undistorted market conditions (i.e. with gradually reduced subsidies and shrinking acceptance of public risk coverage for economic, technological or political reasons).

This article addresses the necessity of advanced risk management tools, and presents a Monte Carlo Simulation (MCS) approach to risk analysis based on a representation of the entire life-cycle of RET-investment projects. Therefore, this paper is structured as follows: Section two briefly describes characteristics of risk and risk management within the framework of RETs. Subsequently, the structure of the developed models and analysis tools, including MCS as a tool to evaluate the risk of an investment in RETs, are introduced and specified for the case of a wood heating plant. This basic introduction to the methodology of risk oriented financial analysis of investment projects is then demonstrated with an application case example of a planned project in Gräfenhainichen, Germany in section four. The paper closes with some concluding remarks and an outlook on future developments.

2. Risk analysis in decentralized renewable energy projects

Risk management of decentralized renewable energy projects consists of a sequence of different measures to identify, assess and allocate project risks. The aim of this procedural chain is to focus attention at potential factors that could have an impact on project cash flows, to analyze qualitatively and quantitatively the possible effects of an adverse event on project earnings and consequently on its viability, and finally to reduce risks by adopting appropriate measures within the project company or by delegating a specific risk to a third party. A minimum requirement an appropriate risk management system must fulfill from a lenders' point of view is the principle that the project should be able to cover debt service with its cash flows even in a worst-case scenario. Therefore, lenders resort to key figures such as the so called debt service cover ratio (DSCR), which determines a projects capability to cover debt servicing from its cash flows, to evaluate a project. From an investor's perspective, the objective of risk management is to assure that the project is able to generate a proper return on equity in a base-case scenario which corresponds to the incorporated risk. For this purpose, fundamental key figures such as the internal rate of return (IRR) or the net present value (NPV), which convey a project's attractiveness to investors, are subject to risk analysis [10].

The individual risks which have an impact on a project's cash flow can be divided into different categories: Pre-completion phase risks, post-completion phase risks and issues common to both phases. Within the scope of pre-completion risks are primarily technical and construction risks whereas supply, operational and market risks constitute mainly post-completion risks. Risks arising from financial, legal, regulatory or environmental spheres build the group of risks common to both phases. Coping with these individual risks is achieved via various measures such as so called turnkey contracts for construction risks, take-or-pay and bring-or-pay agreements or other contractual agreements for market risks and e.g. insurance policies for environmental and operational risks, to name but a few [11]. Nevertheless, risk positions stay relevant even with these measures so that there is a need for investors and lenders to assess the remaining entrepreneurial risk. Therefore, in the following a MCS approach is presented.

3. A Monte Carlo Simulation approach to risk analysis – the method and toolkit

So far, Monte Carlo techniques have rarely been used within the context of risk management of renewable energy infrastructures as they require considerable data processing and the definition of probability density functions for random input variables such as fuzzy or uncertain design and forecast parameters. Nevertheless, some examples exist such as MCS applications to wind energy [12,13] or within the context bioethanol production [14].

The approach presented in this paper focuses on bio-energy infrastructures and analyzes the financial risk for investors and lenders by subjecting the NPV of bio-energy projects to an MCS. Prior to describing the methods chosen, some definitions are necessary.

The project-NPV $y_{\mathrm{NPV},0}$ is defined by equation (1)

$$y_{\mathrm{NPV},0}(T, i_{\mathrm{D}}) = \sum_{\tau=1}^{T} \mathrm{CF}_{\mathrm{tot},\tau}(1+i_{\mathrm{D}})^{-\tau} \tag{1}$$

with $y_{\mathrm{NPV},0}$: net present value related to $\tau = 0$

$\mathrm{CF}_{\mathrm{tot},\tau}$: total cash flow (CF) in period τ including investment, operational, financing cash flows and the liquidation revenue for $\tau = T$

i_{D}: discount interest rate (measure of opportunity cost)

T: number of balance periods (e.g. years)

A zero-NPV indicates that investors receive complete repayment of the capital invested plus an appropriate interest according to the discount interest rate i_{D}. A negative NPV denotes that the investment cannot generate sufficient returns in order to compensate for opportunity costs. Positive NPV-values classify investment projects to be above average expectations of profitability. The investor expectations with respect to proper interest on equity are represented by the discount interest rate i_{D} which influences the NPV-value significantly and serves as an indicator of opportunity cost.

The NPV was chosen as a major comprehensive measure of financial feasibility and project profitability since it is easy to understand, convincing and practical, even for those (potential) project participants with little background in investment analysis [15]. This accessibility is of particular importance within the financial analysis of decentralized renewable energy infrastructures where local stakeholders are often active drivers for the realization of infrastructure projects, but lack any investment analysis knowledge and therefore need practical tools to handle and overcome this constraint [16].

The financial project risk R of negative project NPVs may be defined as:

$$R_{\mathrm{NPV}<0}(x_1 \ldots x_n;\ i_{\mathrm{D}}) = \int_{-\infty}^{0} \mathrm{pdf}\left(\tilde{y}_{\mathrm{NPV},0}\right) \mathrm{d}\tilde{y}_{\mathrm{NPV},0} \tag{2}$$

with $R_{\mathrm{NPV}<0}$: cumulated risk of negative project NPV (product sum of negative NPVs and their probabilities),

$\mathrm{pdf}(\tilde{y})$: probability density function (pdf) of the project NPV $\tilde{y}$