GEORG SIMON OHM
UNIVERSITY OF APPLIED SCIENCES NUREMBERG

INTERNATIONAL BUSINESS PROGRAMS

*Master Program in International Finance and Economics (MiFE)*

SEMINAR PAPERS IN INTERNATIONAL FINANCE AND ECONOMICS

*Center for Applied International Finance and Development (CAIFD)*

# Renewable Energy Generation from Biomass – Biogas in India

*Authors:*

*Riek, Isabell; Rücker, Angelika; Schall, Theresa; Uhlig, Manuela.*

.

*Seminar Paper 6/2012*
*ISSN 2191-4850*

# Table of Contents

## List of Figures

## List of Tables

## List of Abbreviations

| | |
|---|---|
| Btu | British thermal unit |
| C | Periodical payment |
| CF | Cash flow |
| CFA | Central Financial Assistance |
| $CO_2$ | Carbon-dioxide |
| CoGS | Cost of Goods Sold |
| d | day |
| EBIT | Earnings before Interest and Tax |
| EBITDA | Earnings before Interest, Tax, Depreciation and Amortization |
| EIA | United States Energy Information Administration |
| FCFE | Free Cash Flow to Equity |
| g | gram |
| GDP | Gross Domestic Product |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH |
| GJ | Gigajoule |
| GSDP | Gross state domestic product |
| ha | Hectare |
| HDI | Human development index |
| i | Nominal interest rate |
| IBEF | India Brand Equity Foundation |
| $\pi$ | Inflation |
| IREDA | Indian Renewable Energy Agency |
| JLG | Joint Liability Group |
| kg | Kilo gram |

| | |
|---|---|
| kWh | Kilo watt hour |
| l | Liter |
| $m^2$ | Square meter |
| $m^3$ | Cubic Meter |
| MFI | Microfinance Institution |
| MNRE | Ministry of New and Renewable Energy |
| n | Number of total periods required to amortize loan |
| NABARD | National Bank for Agriculture and Rural Development |
| NBMMP | National Biogas and Manure Management Program |
| NGO | Non-Governmental Organization |
| $NH_3$ | Methane |
| NBFCs | Non-banking financial companies |
| NPV | Net Present Value |
| OECD | Organization of economic cooperation and development |
| OWDM | Orissa Watershed Development Mission |
| p.a. | Per annum |
| PPP | Purchasing Power Parity |
| PV | Present Value |
| $r_E$ | Expected return |
| RBI | Reserve Bank of India |
| r | Real interest rate |
| RIDF | Rural Infrastructure Development Fund |
| Rs | Indian Rupee |
| SG&A | Selling, General and Administrative |
| SHG | Self Help Group |

| | |
|---|---|
| TERI | The Energy and Resource Institute |
| yr | Year |

# 1. Introduction

"Energy has been universally recognized as one of the most important inputs for economic growth and human development" (India Energy Portal 2012, p. 1). The presented domestic biogas project can support this development and use existing biomass in rural areas of India to supply the population with an efficient and decentralized form of energy.

This paper aims to analyze if the installation of domestic biogas plants in a rural area of Orissa, India can be profitably undertaken by the executing company, if rural households can finance those plants, and if non-financial benefits arise through the installation of such a plant.

The reader is introduced to the project setup and the three hypotheses that are analyzed throughout this work. The general framework provides an overview about the economic situation of India and Orissa and the general energy situation as well as in relation to biogas. Additionally, some information is given on the legal and institutional situation accompanying the biogas plant project. In the main part, the profitability of the project is assessed followed by the analyses of the feasibility for farmers in rural Orissa. As a third aspect, non-monetary benefits are taken into account and analyzed. Finally, a conclusion is given.

## 2. Description of the Project

Biomass is one of the major energy sources used in rural India covering nearly 96% of energy sources, however its utilization is highly inefficient due to a lack of proper stoves in most households (Reddy and Ravindranath, 1987). Through the installation of a biogas plant and by providing more efficient stoves and biogas lamps to low and middle income receivers in rural India, a community can be provided with a more efficient alternative source of energy due to its wide availability in villages involved in cattle breeding and agricultural production. Due to this, an agricultural-based village - Bhabinarayanpur (84˚ 53'E, 19˚16'N) - located in the coastal region of the East-Indian state Orissa is chosen based on a study undertaken by Nisanka and Misra (1990). The decision to choose Orissa is based on the state's high potential to implement further biogas plants and its advantageous climatic conditions to run such a plant (NABARD, 2012; Kossmann, Poenits and Habermehl, 1997a). The paper by Nisanka and Misra (1990) is selected due to the reliable and precise data given for the respective village. Finding reliable data, especially for rural areas in Orissa, is a constant issue. Even though the research undertaken in the paper by Nisanka and Misra (1990) can be seen as a historical base for further research, the quality and accuracy of the data is the decisive factor in selecting the paper as the base case for this work.

The respective village Nisanka and Misra (1990) chose to examine consists of 125 ha of land and 138 households. Income is mainly generated through selling agricultural products on local markets, reflecting the overall situation in Orissa where 60% of its workforce is occupied in this sector (Institute of Applied Manpower Research, 2011). The region the village is located in enjoys a mainly sub-humid climate, which allows running the biogas plant at consistent capacity throughout the year (Nisanka and Misra, 1990). Within this project, approximately 40% of households in the village will receive a domestic biogas plant.

A newly founded project company will install the biogas plant as a turnkey project. As figure 1 shows below the non-governmental organization (NGO) Gram Vikas as the parent company provides the project company with equity, either with 100% or 30% equity, yet - for simplicity reasons - receives no payment (e.g. in form of dividend) in return due to the non-profit aspect of the biogas plant project. The NGO

Gram Vikas was chosen due to its strong presence in the state of Orissa, the location of the respective village, and its long experience in providing poor households in Orissa with domestic biogas plants first starting in 1986 (Gram Vikas, 2012a; Gram Vikas 2012b)[1]. Moreover, Gram Vikas supports Self Help Groups (SHG) by providing "[…] basic record keeping and financial training […]" as well as linking them to local banks for microloans (Gram Vikas, 2012c). Even though the newly founded project company will set up Joint Liability Groups (JLG), the experience in microfinance through the parent company Gram Vikas will ease the work of the project company. In order to further train the project company's employees in how to deal with microfinance customers and the specific characteristics in this field, an external consultant specializing in microfinance will be hired for the time of the project.

The project company qualifies for a loan under the Rural Infrastructure Development Fund (RIDF), which was established under the National Bank for Agriculture and Rural Development (NABARD) in 1994, which is"[...] responsible for regulating credit flow and promoting integrated development in rural areas" (Johnson and Meka 2010, p. 5; NABARD, 2011). The loan will be provided through the NABARD nodal department - the Finance Department of the State Orissa - carrying out the loan providing process of the RIDF (NABARD, 2011).

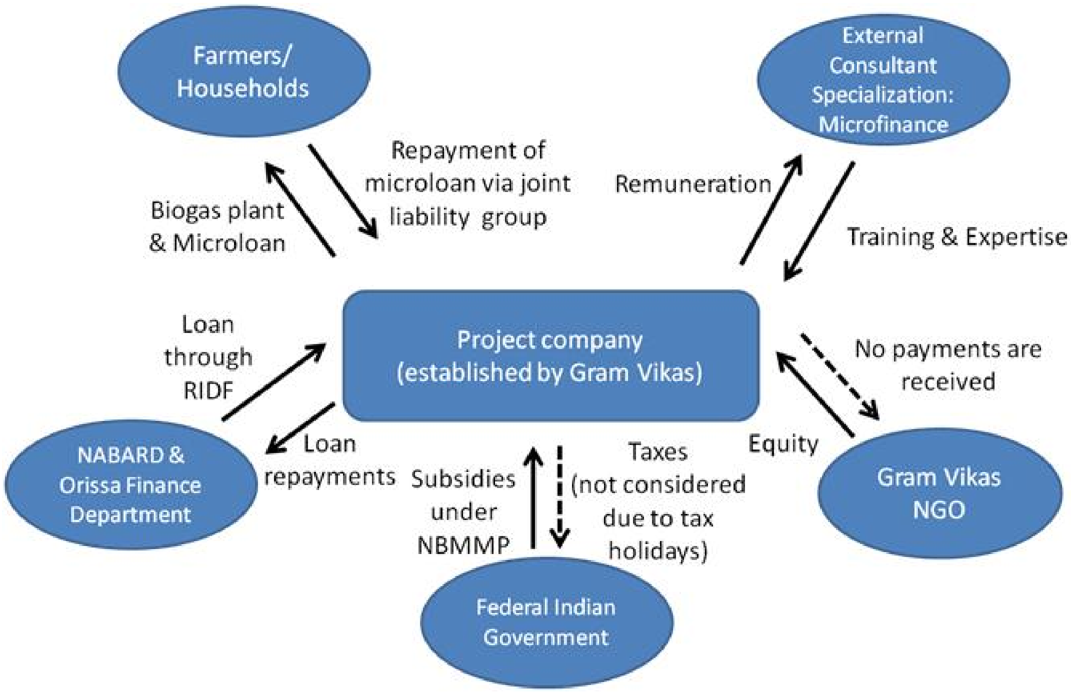
Additionally, the project company will have the opportunity to benefit from a fund of the National Biogas and Manure Management Programme (NBMMP), but does not have to pay taxes to the state and federal government "[...] presuming the non-existence of taxes on traditional energy sources" such as biogas (Kossmann, Poenits, and Habermehl, 1997c, p. 14; Government of India – Ministry of New and Renewable Energy, 2009).

Alternative financing methods for the project company are considered as seen in figure 1 below. The first and second scenario will look at a 100% equity financing of the biogas project through Gram Vikas. Scenarios three and four will consider an equity ratio of 30%. The remaining 70% debt will be raised through the RIDF. Subsidies through the NBMMP are considered in the second and fourth scenario. In order to allow households to finance the biogas plant independently, the project com-

[1] For a detailed description of the NGO Gram Vikas see Appendix A.

pany will provide microloans at the amount needed to fund the family size biogas plant, a new required stove and two biogas lamps. The amount of the loan will differ depending on the subsidies received under NBMMP. The project itself covers costs and takes into consideration inflation over the useful life of the project, hence net present value (NPV) must at least equal zero.

Figure 1: Setup of the Project




Source: Own illustration

Based on the solutions derived from the project profitability calculations as well as the loan calculations hypotheses one and two will be analyzed. Additionally, hypothesis three will look at benefits that can be derived from using a family size biogas plant.

*The first hypothesis* states that financing the biogas plant project will be profitable for the newly established project company over the plants' useful life of 15 years. "Profitable" in this case means, that the project's NPV equals zero at least considering real cost of equity as the discount rate. The above stated argument will either be proven or disproven.

*The second hypothesis* defines that households within the analyzed village are able to raise funds in order to finance the biogas plant on their own, either in absence of subsidies or in combination with them. It shall be proven if a household's income and the additional monetary benefits they obtain through the plant installation can cover loan costs.

*The third hypothesis* will theoretically assess to what extent the biogas plant will derive non-financial benefits for households in the respective village. Benefits include improved health benefits, social benefits related to education and gender issues, and local environmental benefits.

Since the project company receives funds exclusively in Rs and pays all invoices in Rupee (Rs), the exchange rate is provided for orientation purposes only. The day exchange rate June, 02 2012 of $ 1 to 56 Indian Rs is considered.

# 3. General Framework

In the following section, the economic situation of India and the state Orissa is introduced. Following this, an overview over the energy market is given as well as an overview over renewable energies. Finally, rural energy consumption in Orissa is described and the energy which is created from biomass or from a biogas plant.

## 3.1. Economic Situation

In the following paragraph, the reader is introduced to the overall situation of the Indian economy and the state Orissa by giving key figures and by looking at the three economic sectors.

### 3.1.1. Economic Situation in India

The Indian government plays a crucial role in economic planning as it introduces five-year plans in order to regulate and manage the Indian economy. In the five-year plans, the government sets targets for the economy in regard to education, health, environment, infrastructure and income (Encyclopedia Britannica, 2012a). The targets of the current eleventh five year plan including the years 2007 to 2012 is to achieve an annual GDP growth rate of 9%-10% (Planning Commission Government of India, 2008a).

India has a population of more than 1.2 billion. Therefore, almost 17.5% of the world population lived in India in 2011 in comparison to China which is the most populated country making up 19.4% of the world population. The world average annual exponential population growth rate from 2000 to 2010 was 1.23%. In comparison, the Indian average annual exponential population growth rate was higher with 1.64% and even more than three times higher than the Chinese, which amounted to only 0.53% (Office of the Registrar General & Census Commissioner, 2011).

In addition, poverty in India is still a key issue especially in rural areas. The poverty line can be defined as "an income level that is considered minimally sufficient to sustain a family in terms of food, housing, clothing, medical needs, and so on" and is recently set at 28.65 Rs a day in urban areas and 22.42 Rs a day in rural areas in India (OECD, 2012; BBC, 2012). In total in 2005, more than 72% of the Indian population lived in rural areas, of which 28.3% lived below the poverty line (Office of the Registrar General & Census Commissioner, 2011; Institute of Applied Manpower Research, 2011). The part of the population who lives below the poverty line has no access to 'mainstream finance' as they are neglected by formal financial institutions (Sundaresan, 2008). Additionally, they do not have the know-how of sustainable energy use (Rao, Miller, Wang and Byrne, 2009).

With a gross domestic product at purchasing power parity (PPP) of $ 4,463 trillion in 2011, India is ranked number four in the world behind the European Union, the United States and China (CIA Factbook, 2012a). Since 2010, GDP growth has slowed down and is forecasted to decrease from 7% to 8% from 2012 to 2013 (World Bank, 2011; Euromonitor International, 2011). In May 2012, the inflation rate of India was at 7.23% and was therefore higher than the calculated average from 1996 to 2011 which accounted to 6.93% (Trading Economics, 2012) (see Appendix B). This average inflation rate is used in the paper in order to adjust historical data and is also assumed to be the future inflation rate.

Due to the fact that India only has a 2.3% share of the world's agricultural area and additionally 17.5% of the world population lives in India, a guaranteed food supply for the population is a major challenge for India's agricultural sector. In 2011, agriculture was still the most important sector with 58% of the population being employed in it (Department of Agriculture & Cooperation, 2011). The agricultural sector contributes 18.1% to GDP in 2011 (CIA Factbook, 2012b). In addition, the proportion on GDP has almost quadrupled compared to the 1950s (Planning Commission Government of India, 2008a).

The industrial sector, accounting for 26.3% of GDP, experienced high growth of 11% from 2006 to 2007 compared to 6.8% between 2002 to 2003 (CIA Factbook, 2012b; Planning Commission Government of India, 2008a).

The services sector, accounting for 55.6% of GDP in 2011, has the highest growth rate since 2002 compared to the other two sectors introduced above (Planning Commission Government of India, 2008a; CIA Factbook, 2012b). The proportion of construction on GDP grew in the last years due to the strong developments in infrastructure and housing. In 2007, the contribution of construction on GDP was around 6.9%

(Planning Commission Government of India, 2008a). Furthermore, tourism is as well an important factor of services as it contributes 6.4% to GDP in 2011 and will further increase to 6.5% of GDP by 2013. Regarding the absolute contribution of tourism on GDP, India is ranked number 12 in the world due to revenues of more than $121 billion (World travel & tourism council, 2012).

### 3.1.2. Economic Situation in Orissa

Orissa is located in eastern India. In March 2011 the total population amounted to approximately 41.9 million; hence around 3.47% of the total population in India lived in Orissa which qualifies this state as number 11 out of 35 states in India in terms of population. In comparison, the most populated state is Uttar Pradesh with a rate of 16.49%, whereas Lakshadweep has a rate of 0.01% of total population as one of the least populated states. The population growth rate of India from 2001 to 2011 lies at about 1.64%, whereas the average growth rate of Orissa is at 1.28% and therefore lies below the average growth rate (Office of the Registrar General & Census Commissioner, 2011). Furthermore, with a Human development index (HDI) of 0.547, India is ranked number 134 of 187 countries in 2011. The country with the highest HDI is Norway with an Index of 0.943, whereas Congo has the lowest HDI with 0.286. The HDI measures life expectancy, mean years of schooling, expected years of schooling and gross national income per capita (United Nations Development Programme, 2011). Mean years of schooling is the time spent at school by people older than 25 years old, as expected years of schooling is the time that a 5-year old child is expected to spend on education. Orissa had an HDI of 0.362 in 2008 which was the second-lowest rate of all Indian states compared to Kerala which had the highest HDI with 0.790 in 2008 (Institute of Applied Manpower Research, 2011).

Orissa’s gross state domestic product (GSDP) increased continuously from 2003 onwards with 6.65%, but decreased between 2008 until 2009 in comparison to the overall Indian GDP rate of 6.65%. When considering the economic sectors, services almost contribute 49% to GSDP in 2009 followed by the agricultural sector with 36% of GSDP and industry with 15% of GSDP (IBEF, 2010). Construction as well as tourism contributes strongly to the high share of services on GSDP with about 25% of value, as transport and communications have a value of 17% (Institute of Applied Manpower Research, 2011). The key industries in Orissa are above all iron and steel, aluminum and mining due to the high availability of natural resources (IBEF, 2010). In regard to mineral output, Orissa is number one in the country. Although the agricultural sector does not contribute to the same extent as other sectors to overall GSDP, 60% of the workforce in Orissa is occupied in this sector (Institute of Applied Manpower Research, 2011). The most important agriculture products in Orissa are "rice, pulses, oilseeds, vegetables, groundnut, cotton, jute, coconut, spices, potato and fruits" (IBEF, 2010, p.61).

A survey undertaken in 2004 by the National Council of Applied Economic Research (2011) shows that Orissa had the lowest income level of India. Rural per capita income per year was at about 3,096 Rs compared to 9,000 Rs of urban per capita income which leads to an average per capita income of 3,450 Rs. In comparison, Himachal Pradesh has the highest annual per capita income with 9,440 Rs in rural and 15,662 Rs in urban areas which amounts to a 9,942 Rs average per capita income. Rural household income per year in Orissa is at about 15,000 Rs compared to 42,000 Rs of urban household income in the state. Therefore, the average household income per year in Orissa lies at 16,500 Rs. In Himachal Pradesh, the state with the highest income levels, rural household income per year amounts to 43,124 Rs and urban household income to 72,000 Rs which is a 46,684 Rs average household income (National Council of Applied Economic Research, 2011). In Orissa, for 83 different job categories including agriculture, the minimum wage for unskilled workers is 90 Rs a day, for semi-skilled workers 103 Rs, for skilled 116 Rs and for highly skilled workers 129 Rs (Government of India – Ministry of Labour, 2011a). To compare, minimum wages in Himachal Pradesh for unskilled workers in the agricultural sector are at 110 Rs a day which is 9,09% more than in Orissa (Government of India – Ministry of Labour, 2011b).

## 3.2. Energy Overview

In this chapter, an overview over the energy situation is given. The overall energy market and energy consumption in India is regarded and the role of renewable energies is shown. Furthermore, the energy consumption in rural areas is analyzed. A definition of biomass is given followed by a description of the functionality of a biogas plant.

### 3.2.1. Energy Market

On August 14, 2005 the former president of India, Abdul Kalam, announced that the nation's ultimate aim has to be energy independence which should be achieved in the upcoming 25 years (India Energy Portal, 2012). Due to the need of energy as an important input factor for economic growth and human development, energy independence is important, and a poor performance of the energy sector can be a major constraint in achieving the GDP growth rate of 10% targeted in the 11$^{th}$ five year plan (Planning Commission Government of India, 2008b)

India is a well-equipped country with fossil as well as renewable energy resources. Until 1980, India had an independent energy policy due to sufficient fossil energy sources such as coal, oil and gas. Thereafter, the demand for energy sources grew at a compounded annual rate of 5.35% between 1981 and 2006 (EIA, 2006). However, domestic supply could not keep up with the increasing demand of energy, not even with a growing share of renewable energy in the time period until 2012. In 2009, over 25% of the total Indian energy requirements were supplied by various sources of renewable energy (EIA, 2011). According to the EIA report, India ranked in 2009 fourth as an energy consumer worldwide after the United States, China and Russia.

Sinha (2008) states that India is facing a critical challenge of accommodating the fast increasing energy demand. According to the author (2008), India gets more and more aware of the fact that it harms its economy with supply disruptions due to energy shortages. To meet the demand and to diminish energy shortages, the country imports up to 35% of its commercial energy resources such as electricity, natural gas and oil (Schweiger, Armistead and Samudrala, 2010). In 2010, India was the world's fifth largest net importer of oil (EIA, 2011). However, the Indian per capita energy consumption is (with 15.9 million Btu /639 kWh) still at a very low level compared to other developing countries (EIA, 2006). One reason for that might be high prices for energy in terms of PPP (TERI, 2006). [2] Another reason could be the insufficient accessibility to various sources of energy. More than 56% of rural households do not

[2] Indian customers pay high prices for energy in purchasing power parity terms. In 2006, the Indian average tariff on PPP basis was 30.8 cents/kWh compared to the US with 7.7 cents/kWh or China with 20.6 cents/kWh.

have access to the electricity grid or do not connect because of poor reliability and inadequate supply (World Bank, 2010a; Mukherji, 2008).

For the upcoming years, energy demand is expected to grow at an annual rate of 5.2% due to increasing population and growing economy (India Energy Portal, 2012). The need of a national energy strategy is given that boosts the domestic energy supply, pursues efficient use of energy and intends to reduce losses in energy transmission and distribution (Mukherji, 2008). This strategy will help to meet the future demand and support GDP growth.

### 3.2.2. Renewable Energy

Source of renewable energy is energy generated from natural sources such as wind, sunlight, tides or plants that are almost inexhaustible and which regenerate relatively quickly compared to fossil sources of energy (Encyclopedia Britannica, 2012b).

India is one of the most attractive countries for renewable energy investments (Schweiger, Armistead and Samudrala, 2010). According to the Ernst and Young all renewable index (2012), India ranks fourth after China, the United States and Germany. Currently, the Ministry of New and Renewable Energy (MNRE) promotes the development of all sources of renewable energy (Schweiger, Armistead and Samudrala, 2010).

A growing share of renewable energy sources provides environmental advantages beside economic and social benefits. Renewable energies can help the country to meet the energy demand with domestic resources and can prevent the nation from large energy import bills which would influence the current account. Moreover they can build up protection against fuel price volatility and reduce the countries dependence on import and vulnerability to increasing energy prices (World Bank, 2010b). Additionally, the country's development can be enhanced by the utilization of unused unemployed land as solar or wind parks and by supporting rural areas in their progress regarding energy supply. A reduction of social disadvantages due to the inaccessibility of the energy grid and convenient energy resources can be achieved through decentralized energy generation (World Bank, 2010b). Furthermore, environmental benefits can be generated. India has obligations to reduce its carbon emissions according to the Kyoto Protocol. According to the World Bank (2010b) report, one gigawatt of energy generated from renewable energy sources instead of fossil energy sources can reduce carbon emissions by 3.3 million tons a year.

India is currently the world's fifth largest producer of energy from wind after Denmark, Germany, Spain and the United States. Other renewable energy resources such as hydro, solar and biomass energy are used to supply the domestic market with energy (India Energy Portal, 2012). As mentioned before, the domestic supply has to grow at a high pace to overcome the demand-supply gap.

Wind and solar energy need certain weather conditions for energy production. Yet, biomass can also deliver energy under volatile weather conditions. Furthermore, biomass is one of the most attractive decentralized sources of energy in order to supply rural areas with energy (Glemarec, 2012; Reddy and Ravindranath, 1987).

### 3.2.3. Rural Energy Consumption in Orissa

The main sources of energy in rural areas are firewood, agro-wastes, kerosene, electricity, diesel and coal. These different sources of energy can be seen in Table 1 as well as their importance given in percentage of total use. Furthermore, the use of rural energy is given for the sectors agriculture, domestic, lighting, industry and transport.

Table 1: Energy source matrix (GJ/yr) [3]

| | Agriculture | Domestic | Lighting | Industry | Transport | Total | % |
|---|---|---|---|---|---|---|---|
| **Firewood** | 0 | 6,544.61 | 0 | 1,082.40 | 0 | 7,627.01 | **80.59%** |
| **Agro-wastes** | 0 | 680.73 | 0 | 700.00 | 0 | 1,380.73 | **14.59%** |
| **Kerosene** | 0 | 0 | 202.08 | 28.45 | 0 | 230.53 | **2.44%** |
| **Electricity** | 93.30 | 0 | 34.31 | 55.32 | 0 | 182.93 | **1.93%** |
| **Diesel & coal** | 1.25 | 0 | 0 | 41.42 | 0 | 42.67 | **0.45%** |
| **Total fuel** | **94.55** | **7,225.34** | **236.39** | **1,907.59** | **0** | **9,463.87** | |
| **% fuel** | **1.00%** | **76.35%** | **2.50%** | **20.16%** | **0%** | **100%** | |

Source: Own illustration based on Reddy and Ravindranath (1987)

The most important fuel contribution in rural India is biomass. With firewood (81%) and agro-wastes (15%) nearly 96% of the energy consumption is covered by biomass. Energy sources such as kerosene and electricity play a minor role in rural In-

[3] For reasons of simplification and missing present data, it is assumed that the energy consumption investigated by Reddy and Rayindranath (1987) are applicable to rural Orissa and did not change over the years.

dia. The lack of importance is due to missing accessibility to the electricity grid and the high prices of energy (Reddy and Ravindranath, 1987). The major consumer of fuel based energy is in the domestic sector (76%) which includes heating and cooking followed by the industry sector (20%) which beside iron and steel production includes also cement, paper, sugarcane production and fishing (Reddy and Ravindranath, 1987).. Following this, Focusing on biomass as a major source of energy for rural areas can be considered as appropriate

### 3.2.4. Energy from Biomass

According to the European Union Directive on renewable energies, biomass includes the biodegradable fraction of products, wastes and residues of biological origin from agriculture (as plants and animals and their by-products), forestry and related industries as well as the biodegradable fraction from industrial and municipal waste (BEC, 2012; ENCROP 2009).

Currently, biomass in India is not used sustainably. In order to produce energy through the use of firewood, the pace of cutting down trees and bushed outpaces their ability to regenerate (Eltrop, 2005). A sustainable generation of energy from biomass in rural India requires the transformation of inefficient or unused biomass from animal waste and plant waste into an efficient energy source. Since India is situated in a biogas conductive temperature zone, biogas energy generation from biomass will be a more efficient use of biomass waste. This biomass waste can accrue from agricultural, industrial or communal area (Flaig, 1998). Regarding different origins, biomass can be agricultural waste and liquid or solid manure; organic industrial waste water and industrial waste itself from plant or animal background and communal waste like sewage sludge.

The production of biomass in rural areas is dependent on the agricultural situation and the amount of given livestock, the local industry (for example breweries, creameries, slaughterhouses or sugar refineries) and the communal circumstances. For operating a plant that produces biogas from biomass, the future development of the above mentioned areas is important for ensuring a sustainable operation. However, India has the largest population of cattle and buffaloes in the world (Rubab and Kandpal, 1995) and the future development might stay stable due to religious reasons. Therefore, the major part of the rural biomass potential can be based on bovine manure.

### 3.2.5. Energy from a Biogas Plant

Biogas is a product of an anaerobic biological process called methan-ogenesis, which takes place without the impact of oxygen and a technical process called biomethanation (Pauss, Naveau and Nyns, 1987). The gas is a mixture of methane ($CH_4$) and carbon dioxide ($CO_2$) as well as parts of oxygen, nitrogen and some other trace gases. Usually, biogas contains 50 to 80% of $CH_4$ and has between 15 and 45% $CO_2$, whereas the carbon dioxide share has a significant influence on the energy value of the gas (Table 2). The purer the biogas the less $CO_2$ is included and the more energy the gas contains. Moreover, the increase in energy is exponential. Therefore, high methane shares are targeted for efficient biogas production.

Table 2: Biogas composition and energy value, Substrates and gas yields

| Methane (CH4) | Carbondioxide (CO2) | kJ/g |
|---|---|---|
| 50% | 50% | 13.4 |
| 80% | 20% | 29.9 |
| 100% | 0% | 50 |

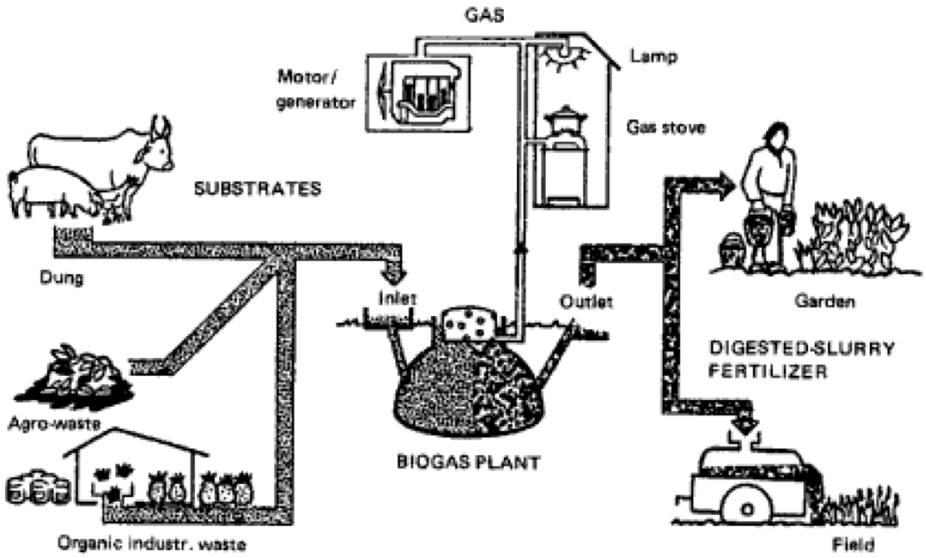
| Substrate | Methane % |
|---|---|
| Sugarcane molasses | 70-75 |
| Cattle manure | 60 |
| Pig manure | 60-70 |
| Corn silage | 50-55 |
| Grass silage | 54-55 |

Source: Own illustration based on Pauss, Naveau and Nyns (1987); Kossmann, Poenits and Habermehl (1997a)

Some of the high methane shares substrates can be seen in Table 2. Different types of substrate have different gas yields. Sugarcane molasses (agro-waste) and cattle manure have high methane proportions and therefore are highly eligible as input factors for a biomass plant (Encorp, 2009). Benefits of the biogas plant include the generated gas as well as highly efficient natural fertilizer given as a side product of the energy generating process (see Figure 2).

The type of biogas plant, which is installed the most in rural areas and which will be installed by the project company is the fixed dome plant type (NABARD, 2012). The fixed dome biogas plant has usually three components: the inlet collection tank, a fermenter and the outlet storage tank (Flaig, 1998).

Figure 2: A typical biogas system configuration




Source: Kossmann, Poenits and Habermehl (1997a)

The heart of the plant is the fermenter, often termed as the biogas plant itself. It is a vessel in which the biomass is metabolized and the biogas is produced. Methane escapes spontaneously from fermentation and no particular process is necessary for the recovery of methane (Pauss, Naveau and Nyns, 1987). The vessel has to be air- and waterproof as well as corrosion resistant and thermally isolated in order to ensure a proper anaerobic biological process. The collection tank is installed in front of the fermenter and it is a container in which the input biomass is collected. Through a flow system, a constant stream of biomass from the collection tank to the fermenter is possible although there is only irregular replenishment. Under optimal conditions of an anaerobic digestion, the slurry warms itself up to the required temperature between 28° and 37°C, which makes additional heating obsolete. Depending on the volume of the digester, the slurry is fully rotten in the vessel within 18 to 35 days. Thereafter, the fermented mixture will be displaced in the third container –the storage tank. It serves as storage place until the mixture is used as a fertilizer for fields. A complete model of a fixed dome biogas plant can be seen in Appendix C.

Assuming a constant flow, sufficient time of more than 20 days and a constant temperature of 35°C will allow reaching the maximum gas yield of the plant (Dissemond, 1993). The biogas produced in a digester can be used as any other combustible gas for end uses such as producing heat, cooking, lighting, or motive power generation (Kossmann, Poenits and Habermehl, 1997a; Rubab and Kandpal, 1995).

A biogas plant of 2 m³ can supply a household with four members with sufficient gas for cooking and lighting. Households of more than four members as given the village of Bhabinarayanpur may need a plant with a higher capacity of 4 m³ (NMRE, 2012). Since the input of to the plant depends on the season, a 4 m³ biogas plant will operate at full workload during peak farming season and produce 4 m³ biogas per day. The plant operates at lower workloads during off-season times. The live expectancy of a biogas plant that is solidly built and maintained properly can amount up to 15 years (Gutterer and Sasse, 1993; Kossmann, Poenits, and Habermehl, 1997b).

## 3.3. Legal and Institutional Situation

The Indian government's energy policy tries to support renewable energy by providing incentives on federal and state government level. One of the main objectives is the supply of energy and electricity to rural areas (International Business Publications, 2003). The upcoming section presents the targets of the Indian government concerning energy and electricity supply mentioned in the eleventh five year plan. Furthermore, the regulations of the Orissa Electricity Reform Act referring to this project are presented.

### 3.3.1. Eleventh Plan

In the eleventh five year plan concerning the years 2007 to 2012, the Indian government emphasizes the importance of electricity for economic growth. It is aware of the fact that the planned GDP growth of 9%-10% per year can only be achieved if India's infrastructure[4] deficit can be surpassed by investing in appropriate projects. The government plans to increase public spending for infrastructure, which includes energy and electricity, from 5% of GDP at the beginning of the plan period to 9% in 2012. However, the plan also recognizes that the capacity of the public sector is not sufficient to cover the resources needed in order to meet the deficit in infrastructure. Therefore incentives are given in order to attract private investment through public private partnerships. The public private partnership program explicitly specifies the aim of "bringing private resources into public projects" and not vice versa (Planning

[4]The Eleventh Plan defines physical infrastructure as electricity, railways, roads, ports, airports, irrigation, urban and rural water supply, and sanitation.

Commission Government of India, 2008b, p. 256). As the given project in this paper is a private one seeking for public funds, it is not possible to raise funds designated to achieve the eleventh five year plan targets for this project. The planned investments in electricity more than doubled from 2,919 billion Rs in the tenth five year plan to 6,665 billion Rs in the eleventh five year plan. However, the share of investments in energy and electricity in total investments remained stable at around 33% (Planning Commission Government of India, 2008b).

Among other physical targets, the plan aims at providing energy and electricity access to all rural households. This is tried to be achieved by a special program called Bharat Nirman which aims at providing electricity to the 125,000 villages which do not have access yet. Investments are planned to amount to 340 billion Rs for this project (Planning Commission Government of India, 2008b). However, as in chapter 3.2.1 already mentioned, the target above has by far not been achieved yet.

### 3.3.2. Orissa Electricity Reform Act

The law applying to the project in the state of Orissa is the Orissa Electricity Reform Act of 1995. According to this regulation, an electricity provider needs a license in order to supply and transmit energy and electricity. The license includes terms and conditions under which the supply of energy has to be carried out. These terms and conditions are set up individually for each license. The holder of a supply license has certain duties such as the development and maintenance of efficient energy supply; in return he is allowed to run the plant. It is therefore not only important to develop a biogas plant within this project, but also to maintain the plant over the useful life. Furthermore, annual reports of current actions taken by the provider and reports of financial details have to be handed in to the Orissa Electricity Regulatory Commission. In case of violations against parts of the Act, the Commission may take actions against the operator. These measures range from fines up to a ban on operating. For this project of providing a source of energy to a village by biogas, it is very important to obtain the license as the Orissa Electricity Regulatory Commission will cease unlicensed projects and disconnect respective plants (Orissa Electricity Reform Act, 1995).

# 4. Profitability of the Project

In the following section, an economic calculation for the biogas plant project is carried out in order to find out if the project is profitable for the NGO (Hypothesis 1). The mission of the project is to deliver family sized biogas fixed dome plants to rural inhabitants in Orissa. As already mentioned in chapter 2, the aim of the project is to supply biogas plants to 40% of Bhabinarayanpur's households, which add up to a sale of 55 plants[5]. After introducing the methodology applied for this chapter, the loan financing methods and the theoretical background regarding subsidies received is presented. Following this, revenue, cost and financial income related to the project are calculated; these sections are strongly linked to each other. Finally, the profitability of the project is assessed and analyzed.

## 4.1. Methodology

For calculating the economic viability of the project, four scenarios are set up. Scenarios one and two assume that 100% of the project company is equity financed, which implies that capital is provided exclusively by Gram Vikas. Scenarios three and four are based on 30% equity financing provided by Gram Vikas and 70% debt received from NABARD. This debt ratio is chosen as project companies usually have a high financial leverage with debt accounting for 70 to 80% of total project capital according to Pollio (1999). The lower bound of this scale is selected to decrease interest payments. Furthermore, as explained in chapter 2, the project company does not have to pay taxes on earnings. Therefore, the importance of a high financial leverage to decrease tax burden can be neglected. The high debt ratio is also appropriate due to the low equity financing possibilities of the NGO. Scenarios one and three furthermore exclude subsidies, whereas scenarios two and four include them. Subsidies are considered as they are a decisive factor in the calculation due to the non-profit character of this project.

[5] 40% of 138 households

Table 3: Scenarios

| Scenario | Financing | | Subsidies |
|---|---|---|---|
| **Scenario 1** | 100% Equity | 0% Debt | Subsidies not considered |
| **Scenario 2** | 100% Equity | 0% Debt | Subsidies considered |
| **Scenario 3** | 30% Equity | 70% Debt | Subsidies not considered |
| **Scenario 4** | 30% Equity | 70% Debt | Subsidies considered |

Source: Own illustration

Project financing is chosen as its criteria are in line with the NGO's objectives. The project is set up as an independent entity and as non-recourse debt is considered, the project debt is separated from the NGO. Repayment of loans is limited to the project itself and lender security only refers to project assets (Pollio, 1999). Project companies usually have problems to raise debt due to missing operating history. Consequently, a further requirement of project financing is economic viability of the project (Finnerty, 2007). This will be proven in the course of this chapter.

Project financing has a special organizational form differing from conventional direct financing. This form is first of all characterized by a finite life. The discussed project lasts 15 years which is equal to the useful life of the biogas plants. Second, free cash flows are distributed directly to project lenders and equity investors. Gram Vikas can consequently decide on reinvestment opportunities independently. In the case of direct financing, managers can decide whether to retain and reinvest earnings or to distribute them to equity holders (Finnerty, 2007). For Gram Vikas, this structure offers the advantage that the NGO can immediately reinvest free cash flows in other charitable projects.

The project company, like the NGO Gram Vikas, is registered under the Indian Societies Registration Act of 1860[6]. In order to do so, "[t]he applicants must register the society with the relevant state Registrar of Societies in order to be eligible for tax-exempt status" (USIG, 2012a).

[6] For a detailed description of the NGO Gram Vikas see Appendix A.

A further important aspect to understand the following chapter thoroughly is the lifetime of the project and the dates when important events occur. The following table presents a timeline of the project.

Table 4: Project Timeline

| Periods (years) | Scenarios | Events |
|---|---|---|
| **0** | 1, 2, 3, 4 | Plants are set up and finalized at December 31st |
| | 2, 4 | First installment of subsidy payments is received |
| | 3, 4 | RIDF disbursement is received |
| **1** | 1, 2, 3, 4 | Plants are transferred to the farmers and start operating at January 1st<br>Maintenance of plants is effected at the end of the year<br>Farmers start to repay their microloans on a monthly basis |
| | 2, 4 | Second installment of subsidy payments and subsidies for maintenance are received |
| | 3, 4 | Repayment of RIDF loan starts in form of 5 payments per year |
| **2-5** | 1, 2, 3, 4 | Maintenance of plants<br>Farmers repay their microloans on a monthly basis |
| | 2, 4 | Subsidies for maintenance are received |
| | 3, 4 | Repayment of RIDF loan in 5 payments per year |
| **6-7** | 1, 2, 3, 4 | Maintenance of plants |
| | 3, 4 | Repayment of RIDF loan in 5 payments per year |
| **8-15** | 1, 2, 3, 4 | Maintenance of plants |

Source: Own illustration

## 4.2. Project Setup

The upcoming sections in this chapter focus on the project's profitability from the perspective of the project company. In order to understand the profitability figures below, the reader is introduced to a detailed explanation of the project structure in advance.

When the project company is founded at the beginning of period 0, total capital of 1,600,000 Rs is needed. For scenarios one and two, this capital is provided exclusively by the NGO Gram Vikas. For scenarios three and four, 30% of capital (480,000 Rs) is provided by Gram Vikas in form of equity. The remaining 70% (1,120,000 Rs) is received from NABARD in form of a long-term RIDF loan. For the provision of equity in all scenarios, Gram Vikas does not receive any payments such as dividends due to the nonprofit character of the NGO. For the loan, NABARD receives redemption and interest payments from period one to seven. Details on this loan are explained in section 4.3.

The project company is responsible for the construction of the biogas plants. These plants are sold to farmers in Bhabinarayanpur. The base price per plant is 23,350 Rs plus 4,000 Rs for equipment that makes the use of biogas in households possible. For scenarios two and four, this price is deducted by subsidy payments. In order to make plants affordable, the project company acts also as a financial institution by providing microfinance loans. Farmers repay the microloan in form of joint liability groups. As a consequence, the project company receives redemption and interest payments from period one throughout period five. The total loan amount per household adds up to 27,350 Rs for scenarios one and three and to 13,045 Rs for scenarios two and four, which equals the price of plant and equipment. The detailed microfinance mechanism as well as the affordability for farmers will be explained in chapter 5. An external consultant specialized in microfinance is involved to give advice regarding the loans given to farmers. In return, this consultant receives remuneration from the project company.

The Indian government is a further player in the biogas project. For scenarios two and four, the project company receives subsidies under NBMMP of up to 14,305 Rs per plant and 112,500 Rs as overhead payments. For details on subsidies, please refer to chapter 4.4. Taxes are not considered as this project focuses on biogas as a traditional energy source and is therefore exempted from tax payments, as explained in chapter 2 (Kossmann, Poenits and Habermehl, 1997c).

## 4.3. Financing

The project company will receive a loan through the RIDF established under the NABARD corresponding to the total amount needed for initial financing. The loan delivery process will be undertaken by the NABARD nodal department - the Finance Department of the State Orissa (NABARD, 2011). In order to qualify for a loan one must either be a state government, a NGO or a Self Help Group. Since the project company qualifies as a NGO under the Indian Societies Registration Act of 1860, the before stated prerequisite is given. Moreover, the project should be of high priority to the state government in order to receive funding. The project will have the ability to benefit from funds of the NBMMP, a nationwide program that is promoted in the state of Orissa (NMRE, 2012). Projects in the fields of agriculture, rural connectivity and in the social sector receive support through the fund. The biogas project falls under the third category 'social sector' since its subcategories include rural energy, which the domestic biogas plant will provide to households in rural Orissa (NABARD, 2011).

The loan calculation is based on an annuity calculation, which "[...] is an asset that pays a fixed sum each [...] [period] for a specified number of years" (Brealey, Myers, and Allen, 2011, p.56). A period within the annuity calculation can be a month, a quarter or concerns any other time period within one year. For the annuity calculation the periodical payments have to be derived, which the project company must pay in order to amortize the loan at the end of each period. The loan the project company receives through the Finance Department of the State Orissa will have a duration of seven years according to RIDF loan terms, which qualifies as a long-term loan based on Grill and Perczynski (2007).

In case the project company fails to compensate its loan obligations on time or completely defaults on the loan, the credit risk remains with the lender – the Finance Department of the state Orissa or the NABARD implementing the RIDF – and not with the borrower – the project company (Grill and Perczynski, 2007). Credit risk can be defined as the risk that the borrower does not comply with all obligations that derive from the contract with the lender (Zegst, 2002).

The nominal interest rate stated under RIDF loan terms amounts to 6.5% p.a. for the year 2011-12. Due to expenses which occur to NABARD or to its nodal departments - the Finance Department of Orissa - an additional 0.5% p.a. is added to the nominal interest rate (NABARD, 2011). In the end, borrowers have to pay a nominal interest rate of 7% p.a. Due to the significantly high inflation rate in India of 6.93% p.a., the real interest rate should be considered as well. Based on the Fisher's theory, "[a] change in the expected inflation rate causes the same proportionate change in the *nominal* interest rate; it has no effect on the required real interest rate" (Brealey, Myers, and Allen, 2011, p.91). This statement is reflected in the formula referring to the Fisher's theory:

$$1 + i = (1 + r) \times (1 + \pi)$$

(i = nominal interest rate, r = real interest rate, π = inflation)
(Brealey, Myers, and Allen, 2011)

If the formula is solved for the real interest rate (r), one derives:

$$r = \frac{1 + i}{1 + \pi} - 1$$

After providing the formula with the nominal interest rate (i) and inflation ($\pi$), one receives the annual real interest rate for the RIDF loan to the project company:

$$r = \frac{1 + 0.07}{1 + 0.0693} - 1$$

$$r = 0.06\%\, p.a.$$

One sees that the real interest rate of 0.06%p.a. significantly lies below the annual inflation rate of 6.93% p.a. in India. Low nominal interest rates are used to promote the financing of projects that might not be feasible under market conditions provided by commercial banks. Therefore, such low real annual interest rates can occur for government sponsored loans as the RIDF loan.

According to RIDF loan terms, the repayment of the loan will start 72 days after completion of the biogas plant and will be undertaken in five equal instalments per year (every 72 days within one year) for the following seven years (NABARD,2011). Due to five payments within one year for a full period of seven years, a total of 35 repayments will be provided to NABARD's nodal department.

Since the loan is repaid in five equal instalments per year, the actual interest rate charged, also called the effective interest rate, differs from the annual interest rate quoted. In the loan terms, the quoted annual nominal interest rate is 7%, yet the effective nominal interest rate is higher and lies at 7.20%. Hence, in reality the project company is not charged a rate of 7% of nominal interest p.a., but an effective nominal interest rate of 7.20%. (For detailed calculation see Appendix J).

For the annuity calculation the periodical payments (C) have to be derived, which the project company has to pay in order to amortize the loan five times a year, beginning 72 days after plant installation. The Present Value (PV) formula of annuity can be used in order to receive the periodical (five per year) payment rate. The following states that the PV of annuity, the amount that needs to be borrowed in order to repay the interest and the principal, is the sum of the periodical payments (C) multiplied by the annuity factor for the respective total period:

$$PV\ of\ annuity = C \times \left[\frac{1}{i} - \frac{1}{i \times (1+i)\hat{}t}\right]$$

and the annuity factor:

$$n - Period - Annuity\ Factor = \left[\frac{1}{i} - \frac{1}{i \times (1+i)\hat{}t}\right]$$

(n = number of total periods required to amortize loan, i = nominal interest rate)

If the formula is solved for C, one derives:

$$(C)Periodical\ Payment = \frac{PV\ of\ annuity}{n - Period - Annutiy\ Factor}$$

(Brealey, Myers, and Allen, 2011)

The loan amount the project company is required to raise depends on the initial financing needs the organization has. Due to the fact that the NGO Gram Vikas will provide the project company with 30% equity, it needs to raise 70% in debt. The project company has a need of 1,600,000 Rs in seed funding, hence requires 1,120,000 Rs in debt which it plans to raise through the RIDF loan. By putting the above introduced loan terms and the total amount required into the annuity factor formula, one derives:

$$35 - Period - Annuity\ Factor = \left[\frac{1}{\frac{0.07}{5}} - \frac{1}{\frac{0.07}{5} \times (1 + \frac{0.07}{5})\hat{}35}\right]$$

$$35 - Period - Annuity\ Factor = 27.52$$

By adding the 35 – period - annuity factor into the before introduced PV of annuity formula solved for C, one derives the five periodical payments that are required to amortize the loan:

$$(C)Periodical\ Payment = \frac{1{,}120{,}00\ Rs}{27.52}$$

$$(C)Periodical\ Payment = 40{,}696.81\ Rs$$

(For detailed calculation see Appendix K)

In order to amortize the RIDF loan over a period of seven years with five equal payments within one year, the project company needs to pay 40,696.81 Rs per period.

## 4.4. Subsidies

Although subsidies are not considered in the base cases of scenarios one and three, they are presented at this point, which is before going into detail into the profitability calculations of the four scenarios. This is important in order to understand revenue and profitability figures of scenarios two and four. To make it clear, this chapter only provides the theoretical background of subsidy payments. For calculations, subsidies are only considered in scenarios two and four and are excluded in scenarios one and three.

The project has the opportunity to benefit from funds of the NBMMP. NBMMP was introduced by the Indian Ministry of New and Renewable Energy to provide clean fuel to households for various purposes, for example cooking. It mainly aims at reducing use of conventional fuels and chemical fertilizers. Furthermore, the program shall improve the situation of women and reduce pressure on forests by allowing the vegetation to recover (Government of India – Ministry of New and Renewable Energy, 2009).

The so called Central Financial Assistance (CFA) is released in two installments: 50% of the funds can be obtained in advance and the remaining 50% are released after the installment period. The second payment depends on the progress of the plant during the implementing year and is only released after a Utilization Certificate is handed in. This has to be done after the financial year of the implementation period is officially over. Therefore, the first part of the fund has to be considered as an inflow in period zero and the second part as an inflow in period one. Furthermore, the project has to consider the risk of not obtaining the second installment if the progress of the project is not satisfactory. The warranty amount of 1,500 Rs is split in five payments: The first payment of 700 Rs is effected in period one and 200 Rs are paid in period two throughout five (Government of India – Ministry of New and Renewable Energy, 2009).

The amount of the CFA depends on the state of implementation and is divided into various items. For the state of Orissa, the following funds apply:

Table 5: Pattern of CFA under NBMMP

| Items for Central Financial Assistance | Family type Biogas Plants under NBMMP (in Rs) |
|---|---|
| **Subsidies per plant** | |
| CFA to beneficiaries of biogas plant ($4m^3$) | 8,000 |
| Turn-key Job Fee including warranty for five year | 1,500 |
| Additional CFA for toilet linked plants | 1,000 |
| Incentives for saving conventional fuels by using biogas in engines | 5,000 (maximum) |
| **Subsidies per operator** | |
| Users training course | 8,000 |
| Staff training course | 2,000 |
| Refresher/Construction and maintenance course | 35,000 |
| Turn-key operator and management course for workers of companies | 67,500 |

Source: Own illustration based on Government of India (2009)

The upper part of the table shows subsidies paid per plant. These subsidies reduce the price farmers have to pay for the plant. The lower part shows subsidies paid for training courses and are kept within the project company. For 55 plants, the following payments are received in the respective period:

Table 6: Total Subsidy Payments per Period

| Period | Payment (Rs) |
|---|---|
| **1** | 408,388 |
| **2** | 446,888 |
| **3** | 11,000 |
| **4** | 11,000 |
| **5** | 11,000 |

Source: Own illustration based on Government of India (2009)

## 4.5. Revenue Calculation

Revenues for the project are mainly received through plant and equipment sales. Plants are produced in period zero and pass over to farmers in period one, which leads to revenue recognition in period one. Excluding subsidies, for scenarios one and three the price farmers pay for a plant is 23,350 Rs plus 4,000 Rs for equipment (NMRE, 2012). Subsidies directly related to an individual plant reduce the price farmers have to pay for the plant to 13,045 Rs including equipment for scenarios two and four. For the scenarios including subsidies, additional revenues are generated in form of overall subsidy payments for training courses. For more details on subsidies, please refer to section 4.4.

As the entire useful life of a biogas plant is 15 years, repair and maintenance has to be ensured over the entire lifetime and is provided by the project company. For maintenance, farmers pay 1,500 Rs per plant per year from period one onwards. Revenue from maintenance increases over the lifetime of the project due to inflation.

Revenues from plant and equipment sales are considered in accounts receivable in period 1. Accounts receivable decrease from period 1 to 5 according to loan repayments effected by the farmers. Revenue from maintenance is considered as cash position.

Appendices F; G, H and I present profit and loss statements for all scenarios reflecting total figures of revenue, cost and financial income for all periods.

## 4.6. Cost Calculation

In the following section, the cost of construction and operation of the biogas plant for the project company will be evaluated. Due to lack of comprehensive sources dealing with data about construction cost, the following section is based on various sources. The result will be cross-checked with sources that supply overall cost figures dependent on size and scale of the biogas project and a proper overall result will be assessed.

Three categories of costs apply: **construction costs** that consist of installment and material costs which depend on the number of plants supplied, **operation costs** such as running and maintenance costs per plant and **selling, general and administrative (SG&A) cost.** The project company needs to pay **construction costs** including all expenditures necessary for the installation of the biogas plant such as work, construction material for the digester the inlet and outlet vessels as well as the gas piping and utilization, heating systems and new devices such as gas stoves and gas lamps.

The construction costs vary among rural areas due to different land, work and material prices. Due to the climatic conditions in Orissa, which is situated in a biogas conductive temperature zone, the plant can be built and operated without any heating system and the costs will therefore be excluded (Kossmann, Poenits and Habermehl, 1997a).

Construction laborer will be remunerated based on a fixed daily rate. Construction costs for a 4 m³ fixed dome family sized biogas plant are shown in Table 7.

Table 7: Unit construction cost for a 4 m³ family sized biogas plant

| | | Cost per unit | | Units | | Total in Rs. | |
|---|---|---|---|---|---|---|---|
| 1 material | pro m³ | Rs. | 2,000 | 4 | m³ | Rs. | 8,000 |
| 4 day labor | per day | Rs. | 90 | 10 | d | Rs. | 3,600 |
| 1 supervisor | per day | Rs. | 129 | 5 | d | Rs. | 645 |
| 1 biogas technician | per day | Rs. | 129 | 3 | d | Rs. | 387 |
| 1 user training | per day | Rs. | 600 | 1 | | Rs. | 600 |
| 1 installation/tests | per plant | Rs. | 250 | 1 | | Rs. | 250 |
| | | | | **Total production costs** | | Rs. | 13,482 |

Source: Own illustration based on Government of India (2012); Government of India – Ministry of Labour (2011a); NMRE (2012); NABARD (2012)

The construction of a biogas plant needs materials as bricks, 6.5 sacks of cement per m³ digester volume, sand as well as two ball valves and steel items (Gutterer and Sasse, 1993). According to NABARD (2012), material costs for the gas holder and the fermenter are 1,500 Rs per 1 m³. Since material is also needed for the inlet collection tank and outlet storage tank and discounts of bulk purchasing need to be respected, .Material cost for 1 m³ of the biogas plant is set at 2,000 Rs. For a 4 m³ biogas plant total material costs will amount to 8,000 Rs.

Construction and installment is very labor intensive and professional supervision and control of biogas technicians is needed. Otherwise the plants may not be gas tight and would pose a risk (Kossmann, Poenits and Habermehl, 1997b). Beside the four unskilled day workers that built mainly the plant, a skilled supervisor guides the day laborers to carry out essential operational activities (Nasery, 2011). The supervisor will be on site every third day, since Gutterer and Sasse (1993) mention five working days per biogas plant installation. Additionally, a biogas technician will visit the plant three days during the whole construction time for installing more complex components. Unskilled day laborers in the construction and maintenance sector earn a minimum of 90 Rs a day (Government of India – Ministry of Labour, 2011a). According to Nasery (2011) a worker receives 50 Rs per day for working at the plant. Since the project company needs to comply with regulation defining minimum wage in India, 90 Rs are paid. Supervisors and biogas technician earn more since they are highly skilled worker. Based on minimum wage highly skilled workers earn 129 Rs a day (Government of India – Ministry of Labour, 2011a). Nasery (2011) calculates with a monthly wage of 2,500 Rs which would be 125 Rs per day assuming 20 working days per month. Total construction related personnel cost sum up to 4,632 Rs.

According to NABARD (2012), the civil engineering costs for the whole construction period of 3-4 weeks would be 13,333 Rs for a 4 m³ biogas plant. However, since the project company builds several biogas plants in the village, the laborers can work gradually. Only the 10 working days (Acara, 2012) for construction need to be paid and construction curing resulting from hardening processes does not need to be paid. Therefore the unit construction costs for labor are lower than suggested by NABARD (2012).

Beside the needed tests and final installation which account for 250 Rs, user training for 600 Rs is provided to the new owners of the biogas plant (NABARD, 2012). Fundamental knowledge about the processes involved in methane fermentation is necessary for operating the plant properly (Kossmann, Poenits and Habermehl, 1997a). Training for the users is therefore essential to ensure an effective use of the plant.

Comparing different academic sources for unit based construction costs including material and the installation of a biogas plant, the expenditure for 1 m³ capacity vary between 2,500 Rs (Kossmann, Poenits and Habermehl, 1997c) and 4,833 Rs (NABARD, 2012). Assuming a 4 m³ capacity family sized biogas plant for six people the total production costs could range from 10,000 Rs to 19,332 Rs. These sources take unskilled labor into account or the latter does not include toilet connection. The total construction cost for one biogas plant of the project company sums up to 14,870 Rs.

Under the condition of a turn-key project the project company sells the 4 m³ fixed dome biogas plant including toilet connection for 23,350 Rs to rural inhabitants (NMRE, 2012).

Additionally, costs for new devices in order to be able to use the produced biogas are needed. A gas storage tank that avoids gas outages costs 800 Rs (10% of the biogas plant material costs) and is installed by the workers during the construction period. For a 4 m³ biogas plant, 22.8 meter piping is needed to connect the plant with the house (NABARD, 2012). Since piping is a mass-produced bulk material, the cost will be about 56 Rs per meter and sum up to a total of 1,277 Rs. New gas stoves cost 2,333 Rs including piping (NABARD, 2012). Finally, the new gas stove, called chullah, for cooking and heating costs 1,056 Rs per unit. Since lighting should be realized with biogas lamps, two of them will be supplied in order to ensure light even when one of them is out of order. One new gas lamp costs 336 Rs according to Alibaba (2012). Two new gas lamps for lighting account for 672 Rs. These costs sum up to 3,805 Rs as it can be derived from Table 8. The project company delivers and installs the devices for 4,000 Rs per household.

Table 8: Cost for new household devices

| | **Cost per unit** | | **Units** | **Total in Rs.** | |
|---|---|---|---|---|---|
| gas storage tank | Rs. | 800 | 10% | Rs. | 800 |
| double burner biogas stoves | Rs. | 1,056 | 1 | Rs. | 1,056 |
| gas lamps | Rs. | 336 | 2 | Rs. | 672 |
| pipes | Rs. | 56 | 22.8 m | Rs. | 1,277 |
| | | | **Total equipment cost per household** | Rs. | 3,805 |

Source: own illustration based on NABARD (2012)

**Operation costs** of a biogas plant are as important as production costs. Operation cost of a biogas plant can be split in running and maintenance costs. Running costs occur for the use of the plant and include efforts needed to run the plant such as collecting and transporting of substrate, water supply as well as supplying the plant (Kossmann, Poenits and Habermehl, 1997c). Since the operation is carried out by the owners of the plant - rural households -, the costs of this individual uses are not occurring to the project company and are therefore not taken into consideration. However, for farmers these costs need to be regarded, as in chapter 5.4.1 can be seen.

Maintenance includes repair and conservation of the plant. Whenever the plant needs to be repaired, they should be made in order to ensure efficient gas production. Material expenses for repairs amount to 5% of the total material construction costs (8000 Rs) and lead to initial 400 Rs annual costs (Engler, Jordan, McFarland and Lacewell, 1997). Maintenance of the plant is needed to assure the overall service of the plant. Regular care and cleaning by the user is as important as annual painting of the metal parts for rust protection. According to NABARD (2012), painting initially costs 467 Rs annually. Furthermore, a biogas technician will look after the plant twice a year and advices the user, checks the pH-value of the slurry to make sure the biogas plant is balanced and check for leaks (Acara, 2012; NABARD, 2012).

Operation costs incurring vary widely and depend on the frequency of use and care for the plant. Average cost of 1,125 Rs for the maintenance work will occur to the project company. However, the maintenance lump-sum for one year initially amounts to 1,500 Rs provided through the project company. It includes the annual painting and minor repairs such as changing of ball valves and fixing other leakages. Additionally the plant will be visited semiannually to give on site supervision and control the work undertaken at the plant. This lump-sum will change annually since the occurring cost to the company will increase due to inflation (Table 9).

Table 9: Initial annual maintenance cost for the biogas plant

| | | Cost per unit | | Units | Total in Rs. | |
|---|---|---|---|---|---|---|
| repair | per plant | Rs. | 400 | 5% | Rs. | 400 |
| paint | per plant | Rs. | 467 | 1 | Rs. | 467 |
| biogas technician maintenance | per plant | Rs. | 129 | 2 d | Rs. | 258 |
| | | | | **Total maintenance cost** | Rs. | 1,125 |

Source: own illustration based on Alibaba (2012); NABARD (2012)

The third category of costs is **selling, general and administrative costs**, which the project company needs to run its business and to be able to offer maintenance and microfinance. The total SG&A expenses that occur to the project company are independent from the amount of biogas plants sold.

To value these expenses, a research paper published by the World Bank is used (Yaron, 1994). This research paper evaluates administrative cost of four financial institutions providing loans to the rural population in emerging countries. These figures are used as a benchmark. Administrative cost of the assessed institutions varies between 4.7 and 16.7% of the average loan portfolio (Yaron, 1994). Expenses for administration from period zero throughout period five are expected to be higher than at the end of the project's lifetime due to efforts related to the microfinance loan, such as collection of farmers' payments. That is why from periods zero to five a share of 16.7% of average loan portfolio is assumed. This share decreases to 4.7% for the periods six to 15. The amount of loans outstanding refers to the base case of scenario one. As inflation is already considered in the total loan amount, it is not added to future administrative cost. Remuneration for the external microfinance consultant is included in these figures.

SG&A expenses occur in form of a shared service level agreement with the NGO as the parent company. Administrative structures, experience, workforce and equipment are provided by the NGO, which in return receives the above presented payments (Hodel, Berger and Risi, 2006).

Systematic depreciation is not considered due to the absence of non-current assets. The project company has no non-current assets as, on the one hand, plants are considered as inventories and pass over to the customers in period one and, on the other hand, assets related to offices and maintenance belong to the parent company and are therefore included in SG&A expenses.

## 4.7. Financial income

Financial income for the project company consists of interest received from farmers for their microfinance loans and interest the project company pays to RIDF for provision of a long-term loan. For scenarios one and three, interest revenues are higher than for scenarios two and four, as the price farmers pay for the plant and therefore the total loan amount is higher due to missing subsidies. As scenarios one and two are completely equity financed, interest expense only occurs for scenarios three and four.

## 4.8. Economic Viability

For the decision if the project is worth to invest in, the net present value (NPV) rule is applied as it is the most common instrument for deciding on investment projects and as it considers the time value of money. According to this rule, all projects with an NPV greater than zero shall be exercised. NPV is the sum of all discounted future cash flows generated by the project (Pollio, 1999). As this project is elaborated out of a non-profit motivation, it is exercised as soon as NPV equals zero. NPV is defined as

$$\text{NPV}=\sum \frac{CF_t}{(1+r_E)^t}$$

($CF_t$ = estimated future cash flows, $r_E$=expected return)
(Pollio, 1999).

Cash flows for the project are calculated as free cash flow to equity (FCFE). The FCFE is preferred to free cash flow to the firm (FCFF) as it offers a more direct approach to evaluate projects. FCFE is defined as

FCFE = Net income
- Investment in fixed capital
- Investment in working capital
+ Net borrowing

(Stowe, Robinson, Pinto and McLeavey, 2007).

The Capital Asset Pricing Model (CAPM) is a method to calculate the cost of equity. It is calculated based on the following formula (Brealey, Myers and Allen, 2011):

$$r_E = r_f + ß * (r_M - r_f)$$

($r_E$ = expected return; $r_f$ = risk-free interest rate; $r_M$ = market return; ß = beta)

First of all, the risk-free rate is assessed. As it is outlined by Bloomberg (2012), the current yield of a ten-year Indian government bond in May 2012 is at about 8.51%. Secondly, the beta coefficient is given which measures the reaction of investments to market movements (Brealey, Myers and Allen, 2011). It can be assumed, that the movements of the investment are similar to the movements of the market and therefore, the beta is set at 1. Finally, the market risk premium is defined. Fernandez, Aguirreamalloa, and Corres (2011) conducted a survey and with 28 answers they conclude, that the market risk premium for the total economy is at around 8.5% in India.

Thus, by using the above mentioned numbers, the result of the calculation is the following:

$$r_E = 8.51\%+1*8.5\%=17.02\%$$

By discounting FCFE of the respective period with cost of equity and summing up the resulting present values, the following NPVs arise. For detailed calculations, please refer to appendices F, G, H and I.

Table 10: NPVs of Scenarios One to Four

| Scenario | Financing | | Subsidies | NPV (Rs) |
|---|---|---|---|---|
| Scenario 1 | 100% Equity | 0% Debt | Subsidies not considered | **58,926** |
| Scenario 2 | 100% Equity | 0% Debt | Subsidies considered | **386,942** |
| Scenario 3 | 30% Equity | 70% Debt | Subsidies not considered | **381,246** |
| Scenario 4 | 30% Equity | 70% Debt | Subsidies considered | **709,261** |

Source: Own illustration

## 4.9. Analysis of Hypothesis 1

The main finding of this chapter is that the scenarios excluding subsidies lead to a much lower NPV than scenarios with the same financing structure but without subsidies scenarios two and four. As mentioned before, the project will be exercised as soon as NPV at least equals zero. The main reason for the difference lies in subsidy payments, which do not occur in scenarios one and three. Although NPV is positive for all scenarios, this shows the project's strong dependence on subsidies.

As a consequence, Gram Vikas should only invest in the project if it is sure to receive the full amount of subsidies. Nevertheless, the risk of not obtaining the second installment of subsidy payments remains, as explained in section 4.4. All other equal, if the second installment and subsidies for maintenance are not received, this has a strong effect on NPV of scenarios two and four. NPV for scenario two finally turns negative from 386,942 Rs to -20,725 Rs. For scenario four, NPV declines strongly as well, however remains positive with 301,595 Rs. This amount is even below NPV of scenario three due to the lower plant price paid by the farmers. Therefore, Gram Vikas should only invest in the project if it is sure to receive the full amount of subsidies and should make sure to fulfill the requirements of NBMMP explained above. An alternative to mitigate this risk might also be a risk transfer to the farmers. This means that households should pay a risk premium for the risk of missing future subsidy payments. As a consequence, plant related subsidies should not be entirely deducted from price. However, this might lead to affordability problems for farmers which will be explained in the following chapter.

A comparison between the two scenarios with the highest NPVs, scenarios two and four, shows that the leveraged project leads to a superior NPV. This is due to credit disbursement in period zero and to a lower interest rate for loans compared to equity. Of course, without discounting, the disbursement would be equalized by redemption. Thus, as NPV considers the time value of money, the disbursement of period zero is worth more than the repayment of periods one to seven. Gram Vikas should therefore decide to lever the project company.

In a nutshell, financing the biogas plant project is profitable for the newly established project company over the plants' useful life of 15 years if Gram Vikas levers the project company with 70% debt and makes sure to receive all future subsidy payments by fulfilling the requirements of NBMMP.

# 5. Feasibility for Households

This chapter assesses the ability of the farmers to afford and finance the biogas plant provided through the project company. Income of rural households is compared to the expenses further taking into account monetary benefits generated through the use of the plant.

For generating income from biogas which is measured in cost savings the biogas output and the substitution effect can be monetized. Additionally, saved time for children and women is taken into consideration since it can be used to generate additional household income. Furthermore, the biogas plant produces high-quality fertilizer, which allows farmers to save money on chemical fertilizer further generating monetary benefits. In the next step, expenses that occur to the farmer are analyzed. First, the financing possibilities for the farmer are examined and thereafter the occurring expenses of the loan with or without subsidies are calculated. Expenses for operation and maintenance of the plant and the opportunity cost for land are added to receive the total expenditures that apply to the farmer. Finally, a comparison of the overall income to the overall expenses is given and the affordability of the plant for rural households is assessed.

## 5.1. General Overview over the Project Village

The following section describes the main findings regarding the project village. Climatic circumstances as well as population and livestock conditions for the rural village of Bhabinarayanpur are given. Due to lack of reliable recent data on rural villages in India, historical figures are used which are adjusted to the present situation.

An agriculture-based village is a typical unit in rural India and can therefore be considered as an individual ecosystem. However, this individual ecosystem is not independent from the external environment. Rural households import energy whenever they cannot cover their demand of energy with wood, kerosene or electricity (Nisanka and Misra, 1990).

The rural area chosen for the project is located in the state of Orissa, east India. Through its costal location at the Bay of Bengal, the tropical climatic conditions are influenced by the sea. Orissa has an average rainfall of roughly 150 $cm^3$ per year per m², which is relatively high compared to other Indian states and therefore a minor problem with water supply (Orissa Tourism, 2012; Nisanka and Misra, 1990; Ravindranath & Chanakya, 1986). According to Gutterer and Sasse (1993), farmers either have own wells or the village uses a common well. More than 96% of villages have access to piped water supply (Government of Orissa, 2012).

The regarded community has a population of 830 inhabitants which are distributed between 137 households. Each household consists of at least six members. These numbers have been projected starting with a basis of 593 inhabitants in 1986 (Nisanka and Misra, 1990) assuming average rural population growth rates of 1.30% and 1.28% between 1986 and 2012 in Orissa, (seeTable 11).

Table 11: Population Development in Bhabinarayanpur, Orissa

| | 1986 | 1990 | 1995 | 2000 | 2005 | 2010 | 2012 |
|---|---|---|---|---|---|---|---|
| Population | 593 | 624.94 | 667.28 | 712.50 | 759.59 | 809.46 | 830.32 |
| Households | 98 | 103.28 | 110.28 | 117.75 | 125.53 | 133.77 | 137.22 |
| Persons per household | 6.05 | 6.05 | 6.05 | 6.05 | 6.05 | 6.05 | 6.05 |

| assumed population growth rates | |
|---|---|
| 1986 - 2001 | 1.32% |
| 2002 - 2012 | 1.28% |

Source: own illustration based on Nisanka and Misra (1990); Growth rates: Government of Orissa (2004); Office of the Registrar General & Census Commissioner (2011)

Cash income per household is generated through cultivating and selling agricultural products such as rice, pulses, oilseeds, vegetables, groundnut, cotton, jute, coconut, spices, potato and fruits (IBEF, 2010, p.61). In Orissa, the average rural per capita income amounts to 3,096 Rs per year (National Council of Applied Economic Research, 2011) and it is assumed that the inhabitants of Bhabinarayanpur earn the average income of the respective state. According to the report of the National Council of Applied Economic Research (2011), the annual household income is 15,000 Rs. Beside the cash income; rural inhabitants have further assets such as livestock and land.

According to projections assuming that average growth rates of 1.30% and 1.28% between 1986 and 2012 in Orissa apply to Bhabinarayanpur, the village counts 154 bullocks, 18 male and 95 female buffaloes, 223 cows, 686 sheep and 101 goats. Additionally, several small animals such as poultry and pigs are given (Table 12).

Table 12: Livestock development in Bhabinarayanpur, Orissa

| Livestock | 1986 | 1990 | 1995 | 2000 | 2005 | 2010 | 2012 |
|---|---|---|---|---|---|---|---|
| bullocks | 110 | 116 | 124 | 132 | 141 | 150 | 154 |
| male buffaloes | 13 | 14 | 15 | 16 | 17 | 18 | 18 |
| female buffaloes | 68 | 72 | 77 | 82 | 87 | 93 | 95 |
| cows | 159 | 168 | 179 | 191 | 204 | 217 | 223 |
| sheep | 490 | 516 | 551 | 589 | 628 | 669 | 686 |
| goats | 72 | 76 | 81 | 87 | 92 | 98 | 101 |
| pigs | 30 | 32 | 34 | 36 | 38 | 41 | 42 |
| poultry birds | 35 | 37 | 39 | 42 | 45 | 48 | 49 |

Source: own illustration based on Nisanka and Misra (1990); Growth rates: Government of Orissa (2004); Office of the Registrar General & Census Commissioner (2011)

Rural inhabitants and animals produce 3.17 million tons of manure per year which equals an average of 62.7 kg per household per day. Since the dung collection of free grazing cattle is difficult and the manure produced during free-range husbandry times cannot be collected in liquid form, farmers can overcome these difficulties and use the night soils to fill the biogas plant. According to NABARD (2012), one bullock produces 14 kg night soils per day. The total manure produced by bullocks is 2,156kg per day which sums up to (2,156kg*365d) 787,049 kg per year since they digest every night of the year. The similar procedure was applied to all other animals and to the population of Bhabinarayanpur (Table 13).

Table 13: Manure resulting from this livestock

| Livestock | 2012 | kg manure per day | kg manure per day total | kg manure per year total |
|---|---|---|---|---|
| bullocks | 154 | 14.0 | 2156.3 | 787,049.3 |
| male buffaloes | 18 | 15.0 | 273.0 | 99,658.8 |
| female buffaloes | 95 | 15.0 | 1428.2 | 521,292.4 |
| cows | 223 | 10.0 | 2226.3 | 812,602.8 |
| sheep | 686 | 3.0 | 2058.3 | 751,274.3 |
| goats | 101 | 1.0 | 100.8 | 36,797.1 |
| pigs | 42 | 2.5 | 105.0 | 38,330.3 |
| poultry birds | 49 | 0.2 | 9.8 | 3,577.5 |
| humans | 830 | 0.4 | 332.0 | 121,180.0 |
| **total** | **1,368** | **61** | **8,690** | **3,171,762.5** |

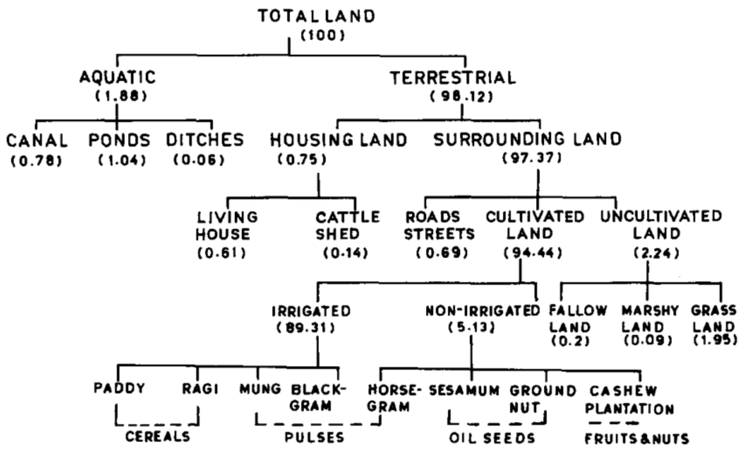
| | | | |
|---|---|---|---|
| persons | 830 | **10.47** | **kg/d** |
| families | 138 | **62.79** | **kg/d** |

Source: own illustration based on NABARD (2012)

Due to the use of night soils, it is assumed that collection is undertaken efficiently and a 100% - 62.79 kg - of generated dung can be used to run the biogas plant.

The inhabitants of the village have 124.89 ha of land available (Nisanka and Misra, 1990). This equals 1,248,910 m². That means, on average every inhabitant owns about 1,506 m². One household therefore holds on average 9,036 m² of land. The total land has 98.12% terrestrial and 1.88% aquatic entities The cultivated terrestrial land that is used for income generation trough farming accounts for 94.44%, hence 117.94 ha in the village are used for growing cereals, pulses, oil seeds, fruits and nuts. Each inhabitant therefore has 1,421 m² of cultivated farming land for generating income and each household has 8,526 m² (Nisanka and Misra, 1990).

Figure 3: Land-use of Bhabinarayanpur




Source: Nisanka and Misra (1990)

Working hours per household needed for cultivating and farming as well as supplying the household with energy amounts to 11.78 h per household based on the available annual working hours according to Bhagavan and Giriappa (1995). Due to the fact that work is undertaken every day in the agricultural sector, annual working hours are divided by 365 days in order to derive daily working hours. Table 14 shows that female household members work more than male household members. Additionally, it is common that children are also involved in daily work

Table 14: Working hours and time spend in the rural household

| Working hours | Average number of working persons | Available working hours per year | Available working hours per day | Available working hours per day/person |
|---|---|---|---|---|
| Adult male | 2.05 | 3950 | 10.82 | 5.28 |
| Adult female | 2.20 | 4000 | 10.96 | 4.98 |
| Child | 1.80 | 1000 | 2.74 | 1.52 |
| **Total** | **6.05** | **8950** | **24.52** | **11.78** |

Source: own illustration based on Bhagavan and Giriappa (1995)

Assuming that females and children spend half of their available working hours per day on collecting wood and dried dung for ensuring fuel energy for heating and cooking and that males spend 10% of their available working hours per day (Bajgain, & Shakya, 2005; Greenpowerindia, 2012), the following efforts for energy generation can be derived:

Table 15: Working hours and time spend on energy purposes

| | Average number of working persons | Former needed working hours for energy generation pp/day | Former needed working hours for energy generation household/day |
|---|---|---|---|
| Adult male | 2.00 | 0.53 | 1.08 |
| Adult female | 2.00 | 2.74 | 5.48 |
| Child | 2.00 | 0.68 | 1.37 |
| **Total** | **6.00** | **3.95** | **7.93** |

Source: own illustration based on Bhagavan and Giriappa (1995); Greenpowerindia (2012)

As seen in Table 15, males spend 1.08 h a day for energy generation whereas females spend 5.48 h per day. Children do also help to generate energy and the total effort of the household sums up to 7.93 hours per day for energy generation.

The above mentioned results are used in the following to generate calculations for assessing the affordability of biogas plants for rural households in Bhabinarayanpur.

## 5.2. Income Generation

In this section, the income that is generated through the operation of a biogas plant is evaluated. First, cash saved through own production of biogas and the need to purchase external energy is assessed. Thereafter, the monetary benefit of saved time is evaluated and subsequently the monetary benefit of the own produced high-quality fertilizer is identified.

### 5.2.1. Monetary Benefit through Biogas

In this section, monetary benefits that could be generated by using biogas instead of fuels such as kerosene are evaluated. Therefore it is analyzed if the manure available is sufficient to cover rural household needs, thereafter the utilization rate of the plant is assessed in order to receive the gas yield that is generated. This gas yield is compared to the monetary value of the gas and to former expenses for energy generation.

As mentioned in chapter 3.2.3, to cover the daily domestic energy consumption needed for cooking and heating, a need of 7,225.34 GJ per year is given (see Table 16). This can be compared to a household energy need of 10.68 kg in manure per day.

In order to receive the daily household need derived from the overall village need, conversions are made. The village has an energy need that equals 7.225 million KJ. Assuming that from 1 g manure a 50% methane content biogas can be produced with an energy value 13 KJ (as mentioned in chapter 3.2.3), the amount of manure needed to cover the domestic energy needs for one year is 539.2 tons. Scaled down to the daily need, this results in 1,477 kilos for the whole village. Since the village has 138 households, one household therefore would need 10.68 kg per day to cover the domestic energy need for cooking and heating.

Table 16: Energy consumption, manure need and biogas yield per household

**Consumption**

| Village | Domestic | | | |
|---|---|---|---|---|
| | need | 7,225.34 GJ/yr | 1 GJ | 1,000,000.0 KJ |
| | | 7,225,340,000 KJ/yr | | |

| Village | Manure | | | | | |
|---|---|---|---|---|---|---|
| | assumption | 1 g | equals | 13 KJ | (50 % Methane content) | |
| | need | 539,204,478 g/yr | | | | |
| | | 539,204 kg/yr | | 1 kg | 1000 g | |
| | | 1,477 kg/d | | 1 yr | 365 d | |

| Family | Manure | | | |
|---|---|---|---|---|
| | assumption | 1 village | equals | 138 families |
| | need | 10.68 kg/d | | |

Source: own illustration based on Reddy and Ravindranath (1987)

The need of 10.68 kg per day can be satisfied since a household has on average 62.7 kg manure per day as described in chapter 5.1. Furthermore, a household has more than five times more manure for energy generation than required. As a consequence, it is possible to cover other consumption sectors such as lighting energy needs as long as they can get access to the biogas produced through the biogas plant. Since the family will have two biogas lamps installed and the manure is sufficient, they can use generated biogas for lighting as well.

In order to utilize the 4 m³ family sized biogas plant at full capacity (100%), a total of six cattle is required (NABARD, 2012). One cattle produces 14 kg a day, hence six cattle produce 84 kg manure per day. Since rural households in Bhabinarayanpur have on average 62.7 kg manure per day available, the biogas plant will not permanently be utilized at full capacity of a 100%. On average the plant will operate at three-fourth (74.64 %) of full capacity Even though the plant does not run at full capacity, energy needs of rural households are covered. Additionally, farmers can use dried dung or crop waste material during farming season or biodegradable household waste throughout the year to run the biogas plant. The average capacity of the plant can be increased and consequently biogas output as well.

According to NABARD (2012), 1 kg manure is equivalent to 0.04 m³ biogas. Since a household has 62.7 kg manure available per day, it equals to 2.5 m³ biogas produced per day. According to Aapkes et al (2011), biogas needs in rural India amounts to 0.132 m³ for cooking and to 0.836 m³ for heating up water per day. Therefore, the produced biogas is sufficient to cover domestic energy needs. Additionally, one biogas lamp requires 0.5 m³ biogas per day (Gutterer and Sasse, 1993). Hence, the two biogas lamps installed in a household require 1 m³ biogas per day. In total, daily biogas demand per household lies at 1.968 m³.

Other sources such as Plöchl and Heiermann (2006) state that a 4 m³ biogas plant generates biogas of 2 m³ per day due to low efficiency in rural areas. The benefit would respectively be lower. Even though a plant working less efficient the energy needs of a rural household could be met.

Rubab and Kandpal (1995) state that the benefit of a biogas plant has to be evaluated in terms of monetary value of the energy source. According to NABARD (2012), 1 m³ biogas has a monetary value of 2.3 Rs. Therefore, the daily produced 2.5 m³ biogas have a value of 5.77 Rs. This implies that monthly production amounts to 173 Rs and annual biogas production to 2,077 Rs (see Table 17).

Table 17: Monetary benefit from biogas production

| | manure (kg) | biogas (m³) | income Rs |
|---|---|---|---|
| Cost of biogas | | 1.00 | 2.30 |
| Energy value of manure | 1.00 | 0.04 | |
| | | | |
| Total per day | 62.70 | 2.51 | 5.77 |
| Total per month (30days) | **1,881.00** | **75.24** | **173.05** |
| Total per year (12 months) | **22,572.00** | **902.88** | **2,076.62** |

Source: own illustration based on NABARD (2012)

Since the biogas produced is used by farmers and injecting surplus into grid is not feasible due to the missing connection in many rural areas of Orissa, the amount of 2,076 Rs is a reference value only and no real income generated.

In the next step, the overall monetary benefit through the use of the biogas plant is evaluated while comparing it to formerly used sources of energy. Rubab and Kandpal (1995) compare the monetary value of the produced biogas with the monetary value of formerly used sources of energy in order to evaluate that benefit.

Since most farmers own cattle and land, they do not pay for the source of energy such as dung and agro-waste. Furthermore, forests and woodlands are regarded as free goods such as air and water, which require no payments for their use or replacement (Nordhaus and Samuelson, 2010). Since farmers pay nothing for the use of wood, dung and agro-waste, they cannot generate a monetary benefit by substituting it. Nevertheless, households can save money by substituting expenses for lighting. They illuminate the house formerly with kerosene and can now use the newly purchased biogas lamps.

According to Reddy and Ravindranath (1987), rural energy needs of the village Bhabinarayanpur for lighting lies at 202.08 GJ per year (see chapter 3.2.3). For the benefit calculation, the given GJ are converted to 202,080 MJ, since Rubab and Kandpal (1995) provide their prices in Rs per MJ. The 1995 unit prices per MJ from Rubab and Kandpal (1995) are inflation adjusted for 17 years. 1 MJ energy from kerosene cost 1995 0.43 Rs and 2012 1.34 Rs (0.43 Rs * 1.0693[17]). Calculating with this inflation adjusted price, the village of 138 households would consume energy for lighting from kerosene of 271,447 Rs per year. Therefore, one household consumes energy for lighting of 1,967 Rs per year. These former monetary expenses for kerosene can now be substituted and the monetary benefit of using biogas for lighting is 1,967 Rs per household and year (Table 18).

Table 18: Former costs for lighting energy production

| | 2012 Energy need in GJ/year village | 2012 Energy need in MJ/year village | 1995 Price of energy Rs/MJ | 2012 Price of energy Rs/MJ | 2012 Price of energy Rs/year village | 2012 Price of energy Rs/year household |
|---|---|---|---|---|---|---|
| **Kerosene** | 202.08 | 202,080 | 0.43 | **1.34** | 271,447 | **1,967** |

Source: own illustration based on Reddy and Ravindranath (1987); Rubab and Kandpal (1995)

These former monetary expenses for kerosene of 1,967 Rs per household and year can now be substituted though the use of biogas for lighting. Monetary benefits are derived through saved energy expenses (Table 18).

### 5.2.2. Monetary Benefit through Saved Time

A rural household can also generate monetary benefit through time savings for energy generation. Saved time can be used for income generating activities which can be undertaken from home.

The current time a rural household spends on energy generation amounts to 7.93 hours per day as mentioned in chapter 5.1. Females and children spend half of their available working hours per day on collecting wood and dried dung to ensure energy for heating and cooking. According to Greenpowerindia (2012), this task can consume between two to four hours per day. Males spend less time on energy generation and need about 10% of their available working hours. The total effort is shared between the two male household members with 0.53 h a day and the two female household members with 2.74 h a day. The two children account for 0.76 h per day (compare Table 14 chapter 5.1, working hours and time spend on energy purposes).

The annual household income amounts to 15,000 Rs (National Council of Applied Economic Research, 2011). For the calculation of income per hour and household member, it is assumed that adults earn an amount equivalent to the annual per capita income and that children earn the spread income. When calculating an income per hour ratio for each household member, the income is compared to the annual available working hours per year as it can be seen in Table 19.

Table 19: Earnings per hour for the rural household

| | Average number of persons | Available working hours per year | Earned income per family/year | Earned income per hour |
|---|---|---|---|---|
| Adult male | 2.00 | 7900 | Rs. 6,192 | **Rs. 0.78** |
| Adult female | 2.00 | 8000 | Rs. 6,192 | **Rs. 0.77** |
| Child | 2.00 | 2000 | Rs. 2,616 | **Rs. 1.31** |
| **Total** | **6.00** | **17900** | **Rs. 15,000** | **Rs. 0.84** |

Source: own illustration based on Bhagavan and Giriappa (1995); National Council of Applied Economic Research (2011)

Males on average earn 0.78 Rs per hour, whereas females earn 0.77 Rs per hour and children earn 1.31 Rs per hour. Children have a comparatively high income, since a minimum working effort according to Bhagavan and Giriappa (1995) is assumed and their earnings constitute the leftover amount of household income to the adult's income per year. Due to the unreliability of the data of the per capita income accounted to children, it will be exempt from the following calculations. With the installation and operation of the biogas plant, the household saves time for income generation since the females and children do no longer need to collect wood and dried dung for energy generation. According to Lawbuary (2012), a regular supply of biogas energy piped to the home removes the daily task of fuel wood gathering.

According to Rubab and Kandpal (1995), the time required for daily work on a family sized biogas plant approximates to half an hour per day. work includes the collection and transportation manure and of water as well as mixing the substrate and feeding the plant (Kossmann, Poenits, and Habermehl, 1997c). Additionally, half an hour is needed for cleaning and maintaining the plant, (NABARD, 2012).

Table 20: Working hours needed for biogas energy generation

| | Average number of working persons | Former needed working hours for energy generation pp/day | Former needed working hours for energy generation household/day | New needed working hours for biogas plant operation pp/day | New needed working hours for biogas plant operation family/day | Total time saved through biogas operation |
|---|---|---|---|---|---|---|
| Adult male | 2.00 | 0.53 | 1.08 | 0.00 | 0.00 | **1.08** |
| Adult female | 2.00 | 2.74 | 5.48 | 0.50 | 1.00 | **4.48** |
| Child | 2.00 | 0.68 | 1.37 | 0.00 | 0.00 | **1.37** |
| **Total** | **6.00** | **3.95** | **7.93** | **0.50** | **1.00** | **6.93** |

Source: own illustration based on Bhagavan and Giriappa (1995)

Females are mainly responsible for energy generation. According to Myles (2002), the operation and maintenance of the biogas plant is also undertaken by women, which receive training and technical support in order to operate the plant. This goes in line with the results of Bajgain and Shakya (2005), which report that using biogas saves three hours per day for a woman. One household saves up to 6.93 hours per day through the implementation of the biogas plant. Of this, males save 1.08 h and females save 4.48 h per day. Children save 1.37 hours, as it seen in Table 20.

In total, men will save 394.2 hours per year (1.08 h * 365 d), women save 1,635.2 h per year (4.48 h * 365 d). According to Greenpowerindia (2012), the average annual time savings for firewood collection and cooking in India approximates to 1,000 h per household provided with a biogas plant. In the case of the biogas project for Bhabinarayanpur, time savings amount to 2,029.2 h per household in one year, which is above average. Children will have 500 additional hours per year (1.37 h * 365) (Greenpowerindia, 2012).

Table 21: Monetary value of time saved through biogas plant operation

| | Time saved in h through biogas plant operation per household/day | Monetary benefit in Rs through biogas plant operation per household/day | Monetary benefit in Rs through biogas plant operation per household/year |
|---|---|---|---|
| Adult male | 1.08 | 0.85 | 309.60 |
| Adult female | 4.48 | 3.47 | 1,265.49 |
| Child | 1.37 | 1.79 | 654.00 |
| **Total** | **6.93** | **6.11** | **2,229.09** |

Source: own illustration based on Bhagavan and Giriappa (1995); National Council of Applied Economic Research (2011)

One household would generate a monetary benefit of 6.11 Rs per day and 2,229 Rs per year (as seen in Table 21). Since children are neglected, the monetary benefit through time savings for energy generation per rural household will be 1,545.09 Rs per year, with a share of 309.60 Rs arising from the males and 1,265.49 Rs arising from the females.

### 5.2.3. Monetary Benefit through Fertilizer

The effluents that are produced through the operation of a biogas plant is a biodegradable fertilizer (Reddy and Ravindranath, 1987). Biological fertilizers that come from a biogas plants have superior nutrient content and has also a pesticidal effect without the harmful effects of pesticides (Vasudeo, 2004).

Through this higher share of NH3, the fermented manure has similar characteristics to mineral fertilizer (Flaig, 1998). The generated biodegradable fertilizer resulting from the operation of the 4 m³ biogas plant can therefore substitute the formerly purchased chemical mineral fertilizers (Greenpowerindia, 2012; NABARD, 2012). Therefore, the digested manure is of monetary value when it is applied in agriculture (NABARD, 2012).

According to NABARD (2012), a 1 m³ biogas plant generates two tons composted manure per year and five tons of refuse that can be used as fertilizer. Since the family-sized biogas plant consists of 4 m³, the output amounts to eight tons of composted manure and 20 tons of refuse. According to OWDM (2011), five tons of fertilizer is needed per season to prepare one ha land and imposing the soil structure. Since one household owns 8,526 m² of land, equalling to 0.85 ha of fertilizer generated through operation of a family-sized biogas plant of 4 m², agricultural needs are covered.

Rubab and Kandpal (1995) state that the benefit accruing to the user from the utilization of digested manure has to be quantified in market prices of mineral fertilizers. According to NABARD (2012), the annually two tons composted manure and five tons of refuse per 1 $m^3$ have a market price of 1,000 Rs per year. For the biogas plants in Bhabinarayanpur, the annual monetary benefit generated through the plant will be 4,000 Rs Furthermore, the productive use of organic fertilizer can generate better returns for farmers further increasing crop yield (Dahiya and Vasudevan, 2003). .

## 5.3. Microfinancing

The literature extensively deals with projects solely financed through donor institutions and via subsidies by the federal and state government of India. The aim of this section is to show a more sustainable way of fully or partly self-financed projects by households within a rural village.

The aim of microfinance is to provide access to finance for the poor and very poor that are usually neglected by formal financial intuitions such as "[…] commercial banks, credit unions, rural banks, and other financial institutions, which are subject to public and private oversight and regulation" (Sundaresan, 2008, p.2). Services offered besides microloans include insurances, saving accounts, or money transfers (RBI, 2011). According to the Reserve Bank of India (RBI) the following characterizes micro financing: borrowers belong to a low-income group, small loan amounts are provided, which are given without any collateral (RBI, 2011). Income generating purposes ought to be the main reason for microloans, yet loans can as well be used for construction and house- maintaining purposes. Finally, the tenure of the loan must be short and the frequency of repayment much higher than for loans with commercial banks.

Lending institutions in the microfinance industry mainly target households "[...] whose annual income does not exceed [...] 50,000" Rs (RBI, 2011, p.5). As shown in section 3.1.2. the average household income in rural parts of Orissa approximates to about 15,000 Rs, which lies well in the income range of the borrower group microfinance tries to target (National Council of Applied Economic Research, 2011). The size of a loan ranges between 10,000 Rs and 15,000 Rs, some can go up to 50,000 Rs for special purposes such as housing and education (RBI, 2011). In case the project fails to receive subsidies, the maximum amount households in the respective village have to borrow amounts to 27,350 Rs, which can be financed via a microloan. The sum of 27,350 Rs. includes the turnkey fee for the biogas plant and the price for a new stove, two biogas lamps, pipes and a gas storage tank. Interest rates according to the RBI report (2011) in the microfinance sector vary between an average effective interest rate of 28.73% charged by smaller for-profit Microfinance Institutions (MFI) up to 36.79% charged by larger for-profit MFIs, "[...] calculated on the mean of the outstanding loan portfolio as at [...] March 2009 and [...] March 2010 [...]" (RBI, 2011, p.11). Interest rates charged by for-profit MFIs are given since they reflect one of the highest in the microfinance industry.

### 5.3.1. Group Lending

Group lending still is the most common form to provide access to financial products to the poor and very poor in India (Johnson and Meka, 2010). "The key feature of group lending is *joint liability*. This says that all group members are treated as being in default if any one member of the group does not repay the loan" (Besley and Coate, 1995, p.2). This forces members to cross-guarantee for each other in case one group associate defaults. Moreover, group lending allows lenders to enforce social collateral, especially in absence of tangible collaterals. Borrowers will fear social sanctions by fellow borrowers within the community if they cannot fulfil their loan requirements. Due to the strong interdependence of people within a community, social sanctions want to be avoided at any cost (Besley and Coate, 1995).

Due to joint liability given in group lending and small microloans poor households are provided with, the project company chose to use microfinance in form of group lending. The following paragraphs give a short overview of the two main forms of group lending used in India, SHGs and JLGs.

SHGs, established by the NABARD under the SHG Bank Linkage Programme in the early 1990s, enjoy a long tradition in India and usually consist of 10 to 15 people - mainly women - that lend from banks such as Regional Rural Banks or other commercial banks under the instruction of the RBI[7]. Allocation of the loan amount is based on the decision of group members and repayments are usually undertaken on a weekly basis, yet not all members will receive a loan at the same time and also have to build up specific amount of savings before they receive a loan through the SHG. All SHG members must cross- guarantee the loan if one member cannot repay the weekly instalment. Banks that lend to SHGs are usually given financial incentives by the NABARD. By 2010, 2.8 million SHGs were established in India (Johnson and Meka, 2010).

Due to the large group size common for SHGs and the choice of loan disbursement within the group, the use of SHGs is not pursued in this paper. SHG are mainly used for community-owned biogas plant and cannot be reliably used for family-size biogas plants as used in this case.

JLGs consist of up to five members which are “[...] jointly responsible for all group members’ repayments” (Johnson and Meka, 2010, p.11). Each member receives an individual loan, mainly through MFIs, but cross-guarantees other group members’ loans. This allows to better match individual lending needs. Repayment of loans is undertaken on a weekly base starting one to two weeks after loan disbursement. Weekly collections are seen as a way to provide financing to the poor and decrease default rates in absence of collaterals. Borrowers usually receive their loan through a loan officer working for the MFI, which allows building up an individual credit history, whereas SHGs can only build up a group credit history (Johnson and Meka, 2010; Field and Pande, 2007).

Payments shortly starting after the loan disbursement are an aspect in financing a biogas plant that can be fulfilled due to the ability to derive gas from it 30 days after installation. However, the tenure of the loan must be adjusted to a period that allows households to repay in small monthly instalments. Since a JLG allows households to receive an individual loan that is backed up through the group cross- guarantee, a microloan provided through the project company given to a JLG is a better alternative in this case compared to a loan given to a SHG. Since the project company di-

[7] Regional Rural Bank: “[S]pecial type of commercial bank with an explicit mandate to focus on rural operations”, which are partly owned by the federal and state government, as well as by single commercial banks (Johnson and Meka, 2010, p. 10).

rectly provides households with a JLG-loan, borrowers build up a credit history with the project company and not with a loan officer as mentioned above.

### 5.3.2. Loan Calculation

Poor households, mainly working in the agricultural sector, have difficulties to afford buying such a biogas plant with cash; hence a need of outside financing is given (Coninck et al., 2005). In order to finance the biogas plant in a more sustainable way than through subsidies and grants only, the newly founded project company provides households in the respective village with microloans, using JLGs to compensate for the risk that occurs due to the lack of collateral. NGOs besides commercial banks and NBFCs MFIs are allowed to lend to JLGs as published in the report concerning guidelines for financing joint liability groups of tenant farmers (NABARD, 2006). The project company qualifies as a NGO based on the Societies Registration Act of 1860. In addition, the project company will work together with an external consultant that is specialized in microfinance in order to gain more expertise in this field. With the help of the external consultant the newly founded project company does not only provide microloans to households, but also collect them after offering specialized training to their employees.

The following section introduces the reader to the general loan terms that apply to the microloan provided to households in the respective village through the project company and the differences that can occur in case the project fails to raise subsidies provided through the NBMMP. Hence, two possible outcomes in relation to the total loan amount can exist which are illustrated in scenario one and two.

The loan calculation is based on an annuity calculation, which "[...] is an asset that pays a fixed sum each [...] [period] for a specified number of years" (Brealey, Myers, and Allen, 2011, p.56). Additionally, the loan provided to households will be a long –term loan, which is a loan with a duration of more than four years as stated by Grill and Perczynski (2007). The loan for the biogas plant will be paid back over a period of five years as suggested by Khandelwal (2008). Shorter durations are regularly practiced in microfinance, yet in the case of the biogas plant, this would this would put too high of a burden on borrowers. Moreover, the duration of the loan will be shorter than the useful life (15 years) of the plant, common practice in financing domestic biogas plants (Kossmann, Poenits, and Habermehl, 1997c).

Loans provided to private households are derived from an external financial mean, the RIDF. Even though funds are received through an external source, the credit risk - in case private households default - still lies with the project company and not with the Finance Department of the state Orissa or the NABARD implementing the RIDF loan. According to Grill and Perczynski (2007), the credit risk for a loan to the end-customer (households in rural Orissa) provided through a public program remains with the issuer of the loan, the project company.

The nominal annual interest rate of the microloan amounts to 12% p.a. based on a field study undertaken by Khandelwal (2008). This interest rate is significantly smaller than what large and small MFIs directly charge their customers.[8] Due to the significantly high inflation rate in India of 6.93% p.a., the real interest rate will also be considered. If the formula referring to the Fisher's theory introduced in 4.3 is solved for the real interest rate (r), one derives,

$$r = \frac{1+i}{1+\pi} - 1$$

(i = nominal interest rate, r = real interest rate, π = inflation)

After providing the formula with the nominal interest rate (i) and inflation (π), one receives the annual real interest rate for the microloan to private households:

$$r = \frac{1+0.12}{1+0.0693} - 1$$

$$r = 4.74\%\ p.a.$$

The real interest rate of 4.74% p.a. substantially lies below the annual Indian inflation rate of 6.93% p.a.. Due to the non-profit aspect of the biogas project such low real interest rates can occur.

Repayment will start 30 days after installation of the plant when the first gas can be derived as explained in chapter 3.2.5., hence the first payment starts at end of period one. Repayments will be undertaken monthly and a total of 60 periods will exist (5

[8] For a detailed discussion on interest rates in microfinance, see chapter 5.3.1. above

years * 12 months per yr). In microfinance loan repayments are usually done on a weekly base as introduced above, yet for this project they will be on a monthly base in order to help lenders to be more flexible. Due to the fact that earnings from farming activities are the main income source for most households in the respective village, weekly payments can easily pressure famer's ability to pay since earnings might differ from week to week. Additionally, monthly collections also lower administrative costs for the project company compared to weekly collections. Even though, weekly repayment instalments are seen as a key feature in microfinance, a study undertaken by Field and Pande (2007) came to the result that "[...] switching from weekly to monthly instalments did not affect client repayment capacity" (Field and Pande, 2007, p.5).

Due to lack of collateral, some bank keep subsidies as interest-free deposits for the time period equal to the maturity of the loan (Khandelwal, 2008). In this case no deposits are kept as a security due to joint liability in group lending, which allows for cross-guarantees of group members to pay each other loan instalments in case of default.

Since the loan is repaid not yearly, but on a monthly base the actual interest rate charged, the effective interest rate differs from the annual interest rate quoted. In the loan terms, the quoted annual nominal interest rate is 12% p.a., yet due to monthly amortization the effective nominal interest rate is higher amounting to 12.68% p.a.. Hence, in reality borrowers are not charged a rate of 12% of nominal interest p.a., but an effective nominal interest rate of 12.68% p.a. (For detailed calculation see Appendix L)

For the annuity calculation the periodical (monthly) payments (C) have to be derived, which the borrower (private household) has to pay in order to amortize the loan at the end of each month, beginning at the end of the first month of plant utilization. The PV formula of annuity can be used in order to receive the monthly payment rate. The following states that the PV of annuity, the amount that needs to be borrowed in order to repay the interest and the principal, is the sum of the periodical payments (C) multiplied by the annuity factor for the respective total periods (60 payment periods):

$$PV\ of\ annuity = C \times \left[\frac{1}{i} - \frac{1}{i \times (1+i)^\wedge t}\right]$$

and the annuity factor:

$$n - Period - Annuity\ Factor = \left[\frac{1}{i} - \frac{1}{i \times (1+i)^\wedge t}\right]$$

(n = number of total periods required to amortize loan; i = discount rate)

If the formula is solved for C, one derives:

$$(C)Monthly\ Payment = \frac{PV\ of\ annuity}{n{-}Period{-}Annutiy\ Factor}$$

(Brealey, Myers, and Allen, 2011)

In the following two scenarios the monthly payments households are require to pay in order to amortize the loan are given. Scenario one looks at the case if no subsidies are given and households in the respective village need to finance the plant on their own, whereas scenario two takes subsidies into consideration.

*Scenario 1: No subsidies, 100% debt financed through microloan*

If the project fails to raise subsidy under the NBMMP, the borrower (rural household) must bear the total turnkey fees for the plant, the new stove and the biogas lamps on their own, in total 27,350 Rs. By putting the above introduced loan terms and the total amount required into the annuity factor formula introduced above, one derives:

$$60 - Period - Annuity\ Factor = \left[\frac{1}{\frac{0.12}{12}} - \frac{1}{\frac{0.12}{12} \times (1+\frac{0.12}{12})^\wedge 60}\right]$$

$$60 - Period - Annuity\ Factor = 44.96$$

By adding the 60 - period- annuity factor into the PV of annuity formula solved for C, one derives the monthly payments that are required to amortize the loan:

$$(C)Monthly\ Payment = \frac{27{,}350\ Rs}{44.96}$$

$$(C)Monthly\ Payment = 608.39\ Rs$$

(For detailed calculation see Appendix M)

Each household needs to pay 608.39 Rs per month over a period of five years in order to fully amortize the loan given through the project company in the absence of subsidies. If the average household in rural Orissa can afford the loan and will be able to repay the monthly instalments in a timely manner will be assessed in chapter 5.5.

*Scenario 2: Approximately 52% subsidies, 48% debt financed through microloan*

If the full amount of subsidy can be received (14,305 Rs per plant), the financing structure changes substantially. In this case, farmers need to finance approximately 48% of the total costs including the turnkey fee for the plant and the new stove on their own. The total amount of debt that needs to be raised then amounts to 13,045 Rs.

Since the payment terms and the interest rate do not change, the 60 – period annuity factor remains as in scenario one.

$$60 - Period - Annuity\ Factor = 44.96$$

However, due to the different debt needs the monthly amortization amount changes substantially. By adding the 60 - period- annuity factor into the PV of annuity formula solved for C, one derives the monthly payments that are required to amortize the loan:

$$(C)Monthly\ Payment = \frac{13{,}045\ Rs}{44.96}$$

$$(C)Monthly\ Payment = 290.18\ Rs$$

(For detailed calculation see Appendix N)

If households receive subsidies, the loan amount will be diminished as well as the monthly payments required to be paid over five years. Households will need to pay 290.18 Rs each month for five years to amortize the loan. As for Scenario one, the affordability of the loan for households in rural Orissa is assessed in chapter 5.5.

## 5.4. Expenses

In addition to financing expenses through the loan, operating expenses such as, running costs as well as maintenance costs occur. Furthermore, the marginal cost of the disuse of farming land for the area where the biogas plant is installed should be taken into account.

### 5.4.1. Expenses through Operation of the Plant

In order to ensure the required gas yields and the appropriate operation of the biogas plant, the feeding mixture consisting of manure and water has to be produced properly. According to NABARD (2012), the mixture ratio can be 50:50. As mentioned in chapter 5.1., one household has 62.7 kg manure available per day. Therefore, a need of 62.7 l of water to produce the mixture is given. When the user of the plant uses dried dung cakes or crop waste to increase the gas yield, the water need will be respectively higher.

With a daily water need of 62.7 l, the annual water need equals 22.9 $m^3$ (Table 22). According to Nisanka and Misra (1990), a rural household owns 1.88% of an aquatic entity such as a canal, a pond and ditches. This share represents 170.1 $m^2$ on average. If the average depth of these aquatic entities is 1 meter, the available amount of water amounts to 170 $m^3$. However, this total amount of water from aquatic entities is needed for cooking; irritating the fields and feeding the biogas plant.

Even if average rainfall of 150 $cm^3$ per square meter is taken into consideration the total amount of 225.9 l water which equals 0.2 $m^3$ would not be sufficient to cover the water needs of the biogas plant operation (Ravindranath and Chanakya, 1986).

Farmers need additional water sources for the operation of the plant. As mentioned before farmers own a well, or share a community well in their village (Gutterer and Sasse, 1993). This can be one source of water.

Table 22: Water needs and resources in Bhabinarayanpur

| **Water needs** | | |
|---|---|---|
| Manure per day | kg | 62.7 |
| Water need per day | l | 62.7 |
| Water need per year | l | 22,885.5 |
| **Water need per year** | **m³** | **22.9** |

| **Water resources** | | |
|---|---|---|
| Aquatic land per village | m² | 23,479.5 |
| **Aquatic land per household** | **m²** | **170.1** |
| Annual rainfall | cm³/m² | 150.0 |
| Annual rainfall per household | cm³ | 225,900.0 |
| Annual rainfall per household | l | 225.9 |
| **Annual rainfall per household** | **m³** | **0.2** |

Source: own illustration based on Nisanka and Misra (1990); Ravindranath and Chanakya (1986)

As mentioned in chapter 5.1., more than 96% of villages have access to piped water (Government of Orissa, 2012). The fair price for 1 m³ water is 9 Rs in 2006 (Indiatogether, 2006). Taking inflation into account, the fair price of water amounts to 13.45 Rs per 1 m³ in 2012 (9 Rs * $1.0693^6$). Therefore, farmers may have expenses of 309.35 Rs (13.45 Rs * 23 m³ for piped water if they feed the plant with piped water only.

Additional expenses for maintenance that occur amount to 1,500 Rs in the first year as described in chapter 4.6. The farmers should use the offered maintenance in order to ensure the proper operation of the plant for its whole lifetime of 15 years (Gutterer and Sasse, 1993; Kossmann, Poenits, and Habermehl, 1997b).

Annual expenses for water of 309.35 Rs and for maintenance of 1,500 Rs underlie price increases due to inflation adjustment and are therefore given for the initial year of operation only. According to a study by Vasudeo (2004), the farmers had a higher crop yield through using the fertilizer from the biogas plant. Farmers might therefore generate additional income due to increased output.

### 5.4.2. Expenses through Disuse of Farming Land

The opportunity cost of the disuse of farming land for the area where the biogas plant is installed should be taken into account. Therefore, income per m² for farming land needs to be evaluated as well as the space needed to set up the plant.. Following this, the opportunity expenses occurring through the disuse of farming land can be calculated.

The villagers of Bhabinarayanpur use 117.94 ha for growing cereals, pulses, oil seeds,fruits and nuts (Nisanka and Misra, 1990). Hence, each of the 830 habitants has 1,421m² of cultivated farming land for generating income. A household with six habitants therefore has 8,526m² farming land.

With an annual per capita income of 3,096 Rs per year (National Council of Applied Economic Research, 2011), earnings for a m² ratio can be assessed. For an individual habitant this ratio amounts to 2.18 Rs per square meter per year. Disuse of 1m² farming land would cost 2.18 Rs per inhabitant.

Since the average household income in Orissa is 15,000 Rs (National Council of Applied Economic Research, 2011) and one household owns 8,526 m³ of farming land, the earnings per m² ratio would be 1.76 Rs per m² per year (see Table 23).

Table 23: Income per m² farming land

| **Land/Income** | | |
|---|---|---|
| Land m² | per capita | 1,421 |
| Income | per capita | Rs. 3,096 |
| **Income per m²** | **total per capita** | **Rs. 2.18** |
| Land m² | per family | 8,526 |
| Income | per family | Rs. 15,000 |
| **Income per m²** | **total per family** | **Rs. 1.76** |

Source 1: own illustration based on NABARD (2012); Gutterer and Sasse (1993)

According to Gutterer and Sasse (1993) a household fixed-dome plant requires an area of about 7 by 4 meters during construction. Thereafter, the plant will need 5 m² (Gutterer and Sasse, 1993). Additionally, 22.8 meters are required to run the gas cable into the users house (NABARD, 2012). Consequently, harvesting land might be affected and must be included into the calculation. In total, used space through the plant will amount to 27.8 m².

Taking the above mentioned earnings per m², farmers have 48.91 Rs less in earnings through disuse of farming land (Table 24).

Table 24: Annual lost earnings through the disuse of farming land

| Annual cost for using the biogas plant | | |
|---|---|---|
| piping area | 22.8 m | Rs. 40.11 |
| | | |
| plant environment | 5 m² | Rs. 8.80 |
| **Total annual cost** | | **Rs. 48.91** |

Source: own illustration based on NABARD (2012); Gutterer and Sasse (1993)

These costs are opportunity costs for the operation of the biogas plant since the farming land on which the biogas plant is installed cannot be used for agricultural purpose. These costs need to be considered when calculating the affordability of the plant for farmers.

## 5.5. Analysis of Hypothesis 2

The following section analyses if households within the respective village are able to operate and maintain the biogas plant and if they are able to finance the biogas plant on their own. This analysis is first carried out without the regard of subsidies and secondly in combination with it. It shall be proven if a household’s monetary benefits obtained through the plant installation and operation can cover loan costs, operation and maintenance cost, as well as opportunity costs of farmland disuse.

**Monetary benefits** from operating the biogas plant occurring to household are of different origin. On the one hand, a household saves a specific amount of cash per year that is otherwise needed to purchase kerosene for lighting (202.08 GJ per year). By using biogas farmers will illuminate their homes with biogas lamps. On the other hand, a household could generate additional income due to saved time of 6.93 h per day. Females will benefit most from the operation of a biogas plant since they save 5.48 h per day due to the omission of dung collection. Time that is saved can be used for further income generating activities women can carry out from their homes. Additionally, a household saves cash that was formerly used for the purchase of chemical mineral fertilizer for their 0.85 ha farming land, which is no longer needed because the biogas plant operation generates effluents which can be used as high quality fertilizer.

**Monetary expenses** that occur to a household through the operation of the biogas plant will occur due to the additional annual water consumption of 23 m³ of piped water, the annual cost for maintenance to ensure the functionality of the plant over the useful life of 15 years and the disuse of 27.8 m² farming land where the biogas plant is installed.

Since costs for kerosene, for chemical mineral fertilizer, and for water and maintenance increase parallel to the inflation rate, monetary benefits and expenses need to be adjusted to the yearly 6.93 % inflation rate. Additional income that is generated through the operation of a biogas plant needs to be adjusted too in order to balance purchasing power to the price increase. In Table 25, the monetary benefits and expenses can be seen for the loan period of five years.

Table 25: Monetary evaluation of feasibility for farmers; years 1 - 5

| **Period** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| Monetary benefit of biogas for lighting | 1,967.00 | 2,103.31 | 2,249.07 | 2,404.93 | 2,571.60 |
| Monetary benefit of saved time & additional income generation | 1,545.09 | 1,652.16 | 1,766.66 | 1,889.09 | 2,020.00 |
| Monetary benefit from fertilizer substitution | 4,000.00 | 4,277.20 | 4,573.61 | 4,890.56 | 5,229.48 |
| **Total monetary benefit** | **7,512.09** | **8,032.68** | **8,589.34** | **9,184.58** | **9,821.08** |
| Expenses for loan w/o subsidies | 7,300.63 | 7,300.63 | 7,300.63 | 7,300.63 | 7,300.63 |
| Expenses for loan with subsidies | 3,482.15 | 3,482.15 | 3,482.15 | 3,482.15 | 3,482.15 |
| Expenses for the operation (water) | 309.35 | 330.79 | 353.71 | 378.22 | 404.43 |
| Expenses for disuse of farming land | 1,500.00 | 1,603.95 | 1,715.10 | 1,833.96 | 1,961.05 |
| Expenses for maintenance | 48.91 | 52.30 | 55.92 | 59.80 | 63.94 |
| **Total expenses w/o subsidies** | **9,158.89** | **9,287.67** | **9,425.37** | **9,572.61** | **9,730.06** |
| **Total expenses with subsidies** | **5,340.41** | **5,469.18** | **5,606.88** | **5,754.13** | **5,911.58** |
| **Overall w/o subsidies** | **-1,646.80** | **-1,254.99** | **-836.02** | **-388.03** | **91.02** |
| **Overall with subsidies** | **2,171.68** | **2,563.49** | **2,982.46** | **3,430.45** | **3,909.50** |

Source: own illustration based on data from chapter 5.2. – 5.4.

The microloan a farmer receives through the project company would require monthly repayments over the period of five years. If the project company does not qualify for subsidies under the NBMMP the loan amount provided to a farmer will automatically be higher than without subsidies. As seen in Table 25 above, farmers have to bear 7,300.63 Rs per year throughout the duration of the loan without subsidies. With the support under NBMMP, the yearly amount is reduced to 3,482.15 Rs. Since the interest rate charged uses the nominal interest rate, hence inflation is already considered, the loan amount charged to farmers remains the same over the period of five years.

The overall analysis shows, that households have to bear a negative income of 1,647 Rs per year in case the project company does not qualify for subsidies. Therefore the operation of the biogas plant is not feasible for farmers since they cannot afford additional costs up to 11 % of their annual household income (1,647 Rs / 15,000 Rs = 10.98 %).

However, with subsidies farmers can afford the operation of the biogas plant and are able to finance the loan. The overall annual income after deducting costs is 2,172 Rs which would be 14 % of their annual household income (2,172 / 15,000 = 14.48 %). Farmers might also afford the plant throughout the years, if females would not find additional employment and the household would not generate more income through saved time (2,172 Rs – 1,545 Rs = 627 Rs).

After the five year period in which the loan needs to be repaid, rural families have additional income equivalent to the amount of monetary benefits minus monetary expenses. The figures are displayed in Table 26. It can be seen, that after 15 years, a farmer can generate up to 14,446 Rs additional income.

Table 26: Monetary evaluation of feasibility for farmers; years 6 - 15

| Period | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|
| Monetary benefit of biogas for lighting | 2,749.81 | 2,940.37 | 3,144.14 | 3,362.02 | 3,595.01 | 3,844.15 | 4,110.55 | 4,395.41 | 4,700.01 | 5,025.72 |
| Monetary benefit of saved time & additional income generation | 2,159.99 | 2,309.68 | 2,469.74 | 2,640.89 | 2,823.90 | 3,019.60 | 3,228.86 | 3,452.62 | 3,691.88 | 3,947.73 |
| Monetary benefit from fertilizer substitution | 5,591.88 | 5,979.40 | 6,393.77 | 6,836.86 | 7,310.65 | 7,817.28 | 8,359.02 | 8,938.30 | 9,557.72 | 10,220.07 |
| **Total monetary benefit** | **10,501.68** | **11,229.44** | **12,007.64** | **12,839.77** | **13,729.57** | **14,681.03** | **15,698.42** | **16,786.32** | **17,949.62** | **19,193.52** |
| Expenses for the operation (water) | 432.46 | 462.43 | 494.48 | 528.75 | 565.39 | 604.57 | 646.47 | 691.27 | 739.17 | 790.39 |
| Expenses for disuse of farming land | 2,096.95 | 2,242.27 | 2,397.66 | 2,563.82 | 2,741.49 | 2,931.48 | 3,134.63 | 3,351.86 | 3,584.15 | 3,832.53 |
| Expenses for maintenance | 68.37 | 73.11 | 78.18 | 83.60 | 89.39 | 95.59 | 102.21 | 109.29 | 116.87 | 124.97 |
| **Total expenses w/o subsidies** | **2,597.79** | **2,777.82** | **2,970.32** | **3,176.16** | **3,396.27** | **3,631.63** | **3,883.31** | **4,152.42** | **4,440.18** | **4,747.89** |
| **Total expenses with subsidies** | **2,597.79** | **2,777.82** | **2,970.32** | **3,176.16** | **3,396.27** | **3,631.63** | **3,883.31** | **4,152.42** | **4,440.18** | **4,747.89** |
| **Overall** | **7,903.88** | **8,451.62** | **9,037.32** | **9,663.61** | **10,333.30** | **11,049.39** | **11,815.12** | **12,633.90** | **13,509.43** | **14,445.64** |

Source: own illustration based on data from chapter 5.2. – 5.4

Since the data is based on the study by Nisanka and Misra (1990) and the village Bhabinarayanpur may have developed different to the assumed projections it is recommendable to renew the study to receive current results and to provide clear evidence about the feasibility of the biogas plant for farmers in Bhabinarayanpur.

# 6. Non-Financial Benefits

The third hypothesis theoretically assesses to what extent the biogas plant derives non-monetary benefits for households in the respective village. These benefits include improved health benefits, social benefits in education and gender empowerment, and local environmental benefits.

## 6.1. Health benefits

As outlined in a report of the organization Unicef (2011), indoor air pollution is a major concern in India. There are four major sources which cause indoor air pollution and out of those, combustion products have the strongest negative influence on pollution (Indian council of medical research, 2001). These combustion products especially arise when burning biomass, the most important energy source in the absence of more efficient energy sources such as a biogas plant. Indoor air pollution causes several diseases as tuberculosis and pneumonia which is especially a threat for children up to the age of five years. There are more than 135,672 cases of death per year among children up to five years due to strong indoor air pollution (Unicef, 2011). The report of United Nations Development Programme (2011) shows that in 2004 there were 435 deaths per million people due to indoor air pollution. Therefore, India is ranked 32 out of 187 countries which have the highest rate of deaths per million people, this number could be reduced as there are several technologies available to decrease indoor air pollution such as the installation of a biogas plant. The national family health survey, based on 260,162 households conducted in 1992, proves that people of 20 or older that live in households mainly burning biomass have a higher tendency to get tuberculosis (Mishra, Retherford and Smith, 1999). In rural areas, the prevalence of tuberculosis due to biomass fuels is higher with 950 incidents out of 100,000 people compared to urban areas with 835 incidents out of 100,000 people.

CMS India (2006) conducted a survey in 2005/2006 with 300 households in Nepal which made use of biogas and compared the amount of diseases before and after the installation of a biogas plant. The results show that the usage of biogas especially decreases the number of respiratory diseases for women, children and men.

Furthermore, the project company ensures the proper functioning of the biogas plant. As explained in Chapter 3.2.5, biomass is metabolized in the fermenter in order to produce biogas. It is ensured that the vessel is air- and waterproof and therefore, a proper anaerobic biological process is possible and the gases from biomass cannot escape. Hence, personal safety is guaranteed for women mainly working on biogas plants. Tasks such as the collection of firewood can as well be reduced, mainly benefiting women and children. In addition, the project company guarantees regular repair and maintenance of the biogas plant over the complete lifetime which ensures the proper functioning of the plant.

## 6.2. Social benefits

Additional benefits which can be achieved are social benefits. These social benefits can positively influence overall education levels as well as improve the overall situation of women.

*Education*

The usage of biogas saves time due to the fact that no dried dung or fuel wood has to be collected which normally takes half of available working hours per day of women and children (Bajgain, and Shakya, 2005). As seen in table 14, men save 1.08 hour per day, women save 4.48 hours per day and children 1.37 hours per day through the operation of the plant. In total, one household saves up to 6.93 hours per day. The time children save can be used to focus more on education.

A survey of the National Council of Applied Economic Research (2011) shows that the literacy rate of men in Orissa lies at 80%, whereas the literacy rate among women amounts to 57%. The average literacy rate for the total population of Orissa lies at 68.5%. India has an average of 79% literacy among men and 58% among women which is on average 68.5%. Thus, almost one third of the total Indian population as well as one third of the population in Orissa cannot read and write. Moreover, approximately 19% of men and 41% of women in Orissa from seven years onwards have never been enrolled in a primary school. The Indian average for people who have never been enrolled in a primary school is at 20% for men and 40% for women. As shown in the United Nations Development Programme (2011) the average rate of years of schooling in India approximately to 4.4 years in 2011, whereas the expected years of schooling should amount to 10.3 years. In Norway, which has the highest ratio of years of schooling, mean years of schooling is at 12.6 years compared to 17.3 expected years of schooling. The ratio for mean years of schooling is relatively low in India which is a reason why the illiteracy rate is so high and simultaneously also decreases the HDI.

Since children save time of 1.37 hours per day due to the installment of the biogas plant, they might be able to attend school and focus on their education, which as well increases the rate of mean years in schooling. In the long-run, this could have a positive effect on the HDI of the village since educational status is improved (CMS India, 2006). Nevertheless, it has to be emphasized that education in India is not for free and if children can go to school depends as well on the ability of families to pay tuition fees (Mukhopadhyay, Ramkumar and Vasavi, 2009).

*Gender benefits*

As outlined by Gram Vikas (2012d), patriarchal dominance especially exists in rural areas in Orissa. Early marriage and sole ownership of property by men are two aspects of this patriarchal system. Mainly women work on the biogas plant as they are responsible for kitchen related tasks (Bajgain, and Shakya, 2005). Therefore, it is important to assess the impact to gender related issues as well.

First of all, as there is less time needed in the kitchen for preparing meals (see table 14), other activities can be undertaken. The kitchen can be used as a drawing or family room and in several households, the family can gather together in the kitchen and women can participate actively in family discussions which increase their participation in decision making (Bajgain, and Shakya, 2005). The study of CMS India (2006) shows activities carried out by women during their saved time as they spend less time in the kitchen. Women attend literacy classes, learn how to read and write, do social work and care about their children.

In addition, women also found that cooperation among family members and neighbors increased due to the installation of the biogas plant as the status of the plant is discussed as well as problems related to the plant (CMS, India, 2006). Therefore, it can be said that the installation also gives an impulse for change in the social environment of women.

## 6.3. Local Environmental Benefits

The installation of the biogas plant also puts less burden on the environment as it is a renewable energy source. As described above, the quality of indoor air in homes increases with the usage of biogas. In addition, since less firewood is needed, deforestation is reduced. An average biogas plant saves more than two tons of firewood per year (CMS India, 2006).

According to Engler, Jordan, McFarland and Lacewell (1997), another benefit of biogas is that it does not produce greenhouse gases. When producing biomass, poor people mainly make use of biofuels as for instance animal dung and firewood. Due to an incomplete combustion, several gases as methane and carbon monoxide are released which has a negative impact on the environment (Indian council of medical research, 2001). As already explained in Chapter 3.2.5, biogas consists of methane ($CH_4$) and carbon dioxide ($CO_2$) as well as parts of oxygen, nitrogen and some other trace gases. Methane is more severe than carbon dioxide and the biogas captures methane and uses it as a fuel (Engler, Jordan, McFarland and Lacewell, 1997). This prevents that methane goes in the atmosphere, an additional benefit for the environment.

## 6.4. Analysis of Hypothesis 3

The main findings of this chapter are that a biogas plant generates several non-financial benefits in form of health benefits, social benefits and local environmental benefits. These results derive from several studies which assess the non-financial benefits by conducting surveys with households that make use of a biogas plant (CMS India, 2006; Bajgain, and Shakya, 2005).

By considering these benefits, Gram Vikas should allocate the project company with equity, which in turn provides rural farmers with biogas plants since it benefits households in a rural village. Nevertheless, it has to be emphasized, that positive changes need some time to develop and cannot be achieved within a short period of time. The installation of the biogas plant solely gives an impulse for change and does not change the overall situation of households.

# 7. Conclusion

The research carried out within this paper shows that the three hypotheses mentioned at the beginning can at least partially be proven. The project is profitable over the plants' entire useful life if subsidies and debt financing are considered. Farmers can afford the plant purchase, the operation and maintenance if subsidies are given. The project derives non-financial benefits in form of health, social and local environmental benefits.

Nevertheless, several limitations of the project emerge. The first one lies within the dependence on subsidies. As already mentioned above, the project is only financeable for Gram Vikas if the full amount of subsidy payments is received. The same applies for the affordability of the biogas plants for households as they are only able to finance a lower price deducted through the implementation of subsidies.

It clearly has to be pointed out that the undertaken research can only be applied to non-profit projects. For profit-oriented companies and organizations, different input data has to be considered which might lead to different results. These differences in input data lie for example in the RIDF loan. Due to the non-profit character of the project, the project company is able to raise debt at a low interest rate, which would not be possible for a commercial project. These aspects deteriorate profitability and a different approach needs to be chosen for a profit-oriented project company.

Limitations arise not only within research results. The research is based on numerous data collected within field studies from the beginning of the 1990s. This data has been adjusted to current levels taking into account inflation and population development. Hence, this cannot give a thorough and completely reliable picture of the present situation and can therefore be seen as a basis for further research. .

As a last aspect, it has to be mentioned that the project not improve the overall situation of households, least of all the situation of the entire village. The implementation of biogas plants in Bhabinarayanpur can however give an impulse to individual households in a very specific field of action. In the scope of energy supply, the paper showed that households can profit from the project. It should therefore be exercised under the conditions presented in this paper.

## References

**Aapkes, J. et al. (2011)** *Cook and sanitation for all people in India.* Available at: http://www.cookandsoapi.nl/img /Cook%20and%20SOAPI-promo.pdf (Accessed: 31 May 2012)

**Acara (2012)** *Bioserv - Service Model Solution.* Available at: http://acara.environ ment.umn.edu/wp-content/uploads/2011/09/BioServ_BPlan.pdf (Accessed: 28 May 2012)

**Alibaba (2012)** *Biogas lamp purchase prices*. Available at: http://www. alibaba.com/showroom/biogas-lamp.html (Accessed: 28 May 2012)

**ASER Centre (2011)** *Annual Status of education report.* Available at: http://www.asercentre.org/ (Accessed: 16 June 2012)

**Bajgain, S. and Shakya, I.S. (2005)** *The Nepal biogas support program: a successful model of public private partnership for rural household energy supply.* Available at: http://siteresources.worldbank.org/INTENERGY/Publications/20918309/NepalBiogasSupportProgram.pdf (Accessed: 01 June 2012)

**BBC (2012)** *Who are the poor in India?.* Available at: http://www. bbc.co.uk/news/world-asia-india-17455646 (Accessed: 28 May 2012)

**Bloomberg (2012)** *India Govt Bond Generic Bid Yield 10 Year*. Available at: http://www.bloomberg.com/quote/GIND10YR:IND (Accessed: 12 May 2012)

**Brealey, R., Myers, S., and Allen, F. (2011)** *Principles of Corporate Finance, 10th ed.* New York: McGraw Hill/Irwin

**BEC (2012)** *What is biomass.* Available at: http://www.biomassenergycentre.org.uk (Accessed 04 April 2012)

**Besley, T. and Coate, S. (1995)** 'Group Lending, repayment incentives and social collateral', *Journal of Development Economics*, Vol. 46, pp. 1-18. Available at: http://ac.els-cdn.com/030438789400045E/1-s2.0-030438789400045E-main.pdf?_tid=14098ae235a831eed053d720cbf9d666&acdnat=1340132375_0190e3 ff5a44fde1140fcf095a1ecb06 (Accessed 25 May 2012)

**Bhagavan, M.R. and Giriappa, S. (1995)** *Biomass, energy and economic and natural resource differentiation in rural southern India*. Available at: http://www.science direct.com/science/article/pii/0961953494000847 (Accessed 20 May 2012)

**CIA Factbook (2012a)** *India.* Available at: https://www.cia.gov/library/publications /the-world-factbook/geos/in.html (Accessed: 15 May 2012)

**CIA Factbook (2012b)** *GDP- Composition by sector*. Available at: https://www.cia.gov/library/publications/the-world-factbook/fields/2012.html (Accessed: 15 May 2012)

**CMS India (2006)** *Biogas Users Survey, 2005/06: Final Report*. Available at: http://www.snvworld.org/sites/www.snvworld.org/files/publications/biogas_users_survey_2005-06_final_report_nepal.pdf (Accessed: 03 June 2012)

**Coninck de, H.C. et al. (2005)** *Providing electricity to remote villages: Implementation models for sustainable electrification of India's rural poor,* Petten, NL: Energy Research Centre of the Netherlands, 2005. Available at: http://www.ecn.nl/docs/library/report/2005/ c05037.pdf (Accessed 15 May 2012)

**Dahiya, A.K. and Vasudevan, P. (2003)** *Biogas plant slurry as an alternative to chemical fertilizers.* Available at: http://www.sciencedirect.com/science/article/pii/014445 6586900132 (Accessed: 03 June 2012)

**Department of Agriculture & Cooperation (2011)** *Annual Report 2010-2011*. Available at: http://india.gov.in/outerwin.php?id=http://agricoop.nic.in/Annual%20 report2010-11/AR.pdf (Accessed: 03 June 2012)

**Dissemond, H. (1993)** *Biogasnutzung aus der Landwirtschaft*, Umweltbundesamt, Wien

**EIA (2006)** *International Energy Annual 2006*. Available at: http://www.eia.gov/emeu/international/energyconsumption.html (Accessed 03 April 2012)

**EIA (2011)** *Country Analysis Briefs*. Available at: http://205.254.135.7/EMEU/cabs/India/pdf.pdf (Accessed 14 April 2012)

**Eltrop, L. (2005)** *Leitfaden Bioenergie. Planung, Betrieb und Wirtschaftlichkeit von Bioenergieanlagen*, Fachagentur Nachwachsende Rohstoffe, Gülzow

**ENCROP (2009)** *Energy from field energy crops - Handbook for energy producers.* Available at: http://www.encrop.net/ (Accessed 15 April 2012)

**Encyclopedia Britannica (2012a)** *India.* Available at: http://www.britannica.com/EBchecked/topic/285248/India/46410/Economy (Accessed: 13 May 2012)

**Encyclopedia Britannica (2012b)** *Renewable Energy.* Available at: http://www.britannica.com/EBchecked/topic/17668/renewable-energy (Accessed: 13 May 2012)

**Engler, C.R., Jordan, E.R., McFarland, M.J. and Lacewell, R.D. (1997)** *Economics and Environmental Impact of Biogas Production as a Manure Management Strategy*. Available at: http://files.harc.edu/sites/gulfcoastchp/publications/economicsimpactbiogas production.pdf (Accessed: 03 June 2012)

**Euromonitor International (2011)** *Country Factfile – India.* Available at: http://www.euromonitor.com/india/country-factfile (Accessed: 03 May 2012)

**Ernst and Young (2012)** *Renewable energy country attractiveness indices – All renewable index.* Available at: http://www.ey.com/Publication/vwLUAssets/CAI_issue_32_Feb_2012/$FILE/CAI_issue_32_Feb_2012.pdf (Accessed: 30 May 2012)

**Flaig, H. (1998)** *Biomasse - nachwachsende Energie. Potentiale - Technik - Kosten*, Expert-Verlag, Renningen-Malmsheim

**Field, E. and Pande, R. (2007)** *Repayment Frequency and Default in Microfinance: Evidence from India.*: Institute for Financial Management and Research Centre for Micro Finance, Chennai. Available at: http://ifmr.ac.in/cmf/publications/wp/2007/20_field_pande-repaymentfrequency.pdf (Accessed 15 May 2012)

**Finnerty, J. (2007)** *Project Financing: Asset-Based Financial Engineering*, 2nd edition. John Wiley & Sons, New Jersey

**Glemarec, Y. (2012)** *Draft-financing off-grid sustainable energy access for the poor*, Energy Policy, March 2012

**Government of India – Ministry of Labour (2011a)** *State-wise and employment-wise minimum wages Orissa.* Available at: http://labour.nic.in/wagecell/Wages/OrissaWages.pdf (Accessed: 31 May 2012)

**Government of India – Ministry of Labour (2011b)** *State-wise and employment-wise minimum wages Himachal Pradesh.* Available at: http://labour.nic.in/wagecell/Wages/HPWages.pdf (Accessed: 31 May 2012)

**Government of India – Ministry of New and Renewable Energy (2009)** *National Biogas and Manure Management Programme (NBMMP).* Available at: http://www.mnre.gov.in/schemes/decentralized-systems/schems-2/ (Accessed: 05 April 2012)

**Government of Orissa (2004)** *Orissa's Urban Population: An Overview*. Available at: http://orissa.gov.in/e-magazine/Orissareview/nov2004/englishPdf/orissaurbanpopulation.pdf (Accessed: 05 April 2012)

**Government of Orissa (2012)** *Water Supply.* Available at: http://www.orissa.gov.in/RD/ruralwatersuplly/pws.html (Accessed: 05 April 2012)

**Gram Vikas (2011)** *Annual report 2010-2011*. Available at: http://gramvikas.org/uploads/file/Annual%20Report%202010-2011.pdf (Accessed 06 June 2012)

**Gram Vikas (2012a)** *About us*. Available at: http://gramvikas.org/index.php?act_id=2&page_id=10 (Accessed: 27 May 2012)

**Gram Vikas (2012b)** *Programmes-LEI & Renewable Energy- Biogas*. Available at: http://gramvikas.org/index.php?act_id=2&page_id=23#Biogas (Accessed: 27 May 2012)

**Gram Vikas (2012c)** *Promotion of Self Help Groups*. Available at: http://gramvikas.org/index.php?act_id=2&page_id=19#SHG (Accessed: 29 May 2012)

**Gram Vikas (2012d)** *Institutionalizing gender in patriarchal rural communities: creating spaces through uncontested domains.* Available at: http://gramvikas.org/uploads/file/Publications/Institutionalising_gender.pdf (Accessed: 13 June 2012)

**Greenpowerindia (2012)** *Biogas Benefits*. Available at: http://www.greenpowerindia.org/biogas_benefits.htm (Accessed: 03 June 2012)

**Grill, W. and Perczynski, H. (2007)** *Wirtschaftslehre des Kreditwesens 41 ed*. Troisdorf: Bildungsverlag EINS.

**Gutterer, B. and Sasse, L. (1993)** *Criteria for Dissemination of Biogas Plants for Agricultural Farm - Biogas Plants for Agricultural Farms,* Bremen, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), 1993

**Hodel, M., Berger, A. and Risi, P. (2006)** *Outsourcing realisieren,* 2nd edition, GWV Fachverlage GmbH, Wiesbaden

**India Brand Equity Foundation (IBEF) (2010)** *Orissa.* Available at: http://www.ibef.org/ download/Orissa_060710.pdf (Accessed: 14 April 2012)

**India Energy Portal (2012)** *Indian energy sector: an overview*. Available at: http://www.indiaenergyportal.org/overview_detail.php (Accessed: 03 April 2012)

**Indian council of medical research (2001)** *Indoor air pollution in India- a major environmental and public health concern.* Available at: http://icmr.nic.in/bumay01.pdf (Accessed: 13 June 2012)

**Indiatogether (2006)** *A fair price for water*. Available at: http://www.indiatogether.org/2006/dec/env-tariff.htm (Accessed: 03 June 2012)

**Institute of Applied Manpower Research (2011)** *India human development report 2011: towards social inclusion.* Available at: http://www.im4change.org/docs/340IHDR_Summary.pdf (Accessed: 14 May 2012)

**International Business Publications (2003)** *India: Energy Policy, Laws and Regulations Handbook – Volume I: Strategic Information and Renewable Energy*. Available at: http://books.google.de/books?id=nB2XgE_JvWcC&printsec=frontcover&hl=de&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=true (Accessed: 16 April 2012)

**Johnson, D. and Meka, S. (2010)** *Access to Finance in Andhra Pradesh.* Chennai: Institute for Financial Management and Research, Centre for Micro Finance & Centre for Microfinance Research Bankers' Institute of Rural Development. Available at: http://www.centre-for-microfinance.org/wpcontent/uploads/attachments/csy/695/CMF_Access_to_Finance_in_Andhra_Pradesh_2010.pdf (Accessed: 16 May 2012)

**Khandelwal, K.C. (2008)** *Country Report on Financing of Domestic Biogas Plants in India*, International Workshop on Financing of Domestic Biogas Plants Bangkok. Available at: www.snvworld.org/files/publications/india_international_workshop_on_financing_of_domestic_biogas_plants_2008.pdf (Accessed: 13 May 2012)

**Kossmann, W., Poenits, U. and Habermehl, S. (1997a)** *Biogas Digest, Volume I - Biogas Basics*, ISAT & GTZ, 1997. Available at: http://www.gtz.de/de/dokumente/en-biogas-volume1.pdf (Accessed: 22. April 2012)

**Kossmann, W., Poenits, U. and Habermehl, S. (1997b)** *Biogas Digest, Volume II – Biogas – Application and Product Development*, ISAT & GTZ, 1997. Available at: http://www.gtz.de/de/dokumente/ en-biogas-volume2.pdf (Accessed: 22. April 2012)

**Kossmann, W., Poenits, U. and Habermehl, S. (1997c)** *Biogas Digest, Volume III – Biogas – Costs and Benefits*, ISAT & GTZ, 1997. Available at: http://www.gtz.de/de/dokumente/ en-biogas-volume3.pdf (Accessed: 22. April 2012)

**Lawbuary, J. (2012)** *Biogas Technology in India: More than Gandhi's Dream?.* Available at: http://www.ganesha.co.uk/Articles/Biogas%20Technology%20in%20India.htm (Accessed: 03 June 2012)

**Mishra, V.K., Retherford, R.D. and Smith, K.R. (1999)** '‘Biomass cooking fuels and prevalence of Tuberculosis in India', *International Journal of infectious diseases,* 3 (3). Available at: http://ac.els-cdn.com/S1201971299900322/1-s2.0-S1201971299900322-main.pdf?_tid=4be12bb5a82bdd4230d38405e604e7a4&acdnat=1339575979_5888e4c09db396aafb156e5b919e199a (Accessed: 12 June 2012)

**Myles, R. (2002)** *Empowering rural poor woman by enhancing income through biogas plant by INSEDA and WAFD in Bhartapur, India*. Available at: www.inseda.org/Case%20studies/Empowering%20rural%20poor%20women%20through%20biogas%20plant.pdf (Accessed: 03 June 2012)

**NMRE (2012)** *Family Type Biogas Plants Programme - National Biogas and Manure Management Programme (NBMMP).* Available at: http://www.mnre.gov.in/schemes/decentralized-systems/schems-2/ (Accessed: 30 May 2012)

**Mukherji, K. (2008)** *Climate Change, Energy Law and India,* in: Patel, BN (2008) *India and International Law*, 2nd edition. Available at: http://www.nijhoffonline.nl/book?id=nij9789004161528_nij9789004161528_i-570 (Accessed: 01 April 2012)

**Mukhopadhyay, Ramkumar and Vasavi (2009)** *Management of elementary education structures and strategies.* National University of educational planning and administration New Delhi

**NABARD (2006)** *Guidelines for Financing Joint Liability Groups of Tenant Farmers*. Available at: http://www.nabard.org/pdf/iba.pdf (Accessed: 06 May 2012)

**NABARD (2011)** *List of schemes for availing subsidy, grants, funding and loans*. Available at: http://indiamicrofinance.com/wp-content/uploads/2011/12/Nabard-Schemes-Funding-2012.pdf (Accessed: 27 May 2012)

**NABARD (2012)** *Model Bankable Projects - Agricultural Engineering – Biogas*. Available at: http://www.nabard.org/modelbankprojects/biogas.asp (Accessed: 19 May 2012)

**Nasery, V. (2011)** *Biogas for rural communities*. Center for Technology Alternatives for Rural Areas, Indian Institute of Technology Bombay. Available at: www.cse.iitb.ac.in/~sohoni/pastTDSL/BiogasOptions.pdf (Accessed: 31 May 2012)

**National Council of Applied Economic Research (2011)** *Human development in India -Challenges for a society in transition.* Available at: http://www.ncaer.org/downloads/Reports/HumanDevelopmentinIndia.pdf (Accessed: 13 May 2012)

**Nisanka, S.K. and Misra, M.K. (1990)** *Ecological study of an Indian village eco-system: Biomass production and consumption*. Available at: http://www.sciencedirect.com/science/article/pii/014445659090030N (Accessed: 01 April 2012)

**Nordhaus, W.D. and Samuelson, P.A. (2010)** *Economics*, 19th international edition. McGraw-Hill, Boston, 2010

**Office of the Registrar General & Census Commissioner (2011)** *Size, growth rate and distribution of population.* Available at: http://www.censusindia.gov.in/2011-prov-results/prov_results_paper1_india.html (Accessed: 14 May 2012)

**Organisation of Economic cooperation and development (2012)** *Poverty line.* Available at: http://stats.oecd.org/glossary/detail.asp?ID=6337 (Accessed: 28 May 2012)

**Orissa Electricity Reform Act (1995)** *India: Energy Policy, Laws and Regulations Handbook – Volume I: Strategic Information and Renewable Energy*. Available at: http://books.google.de/books?id= nB2XgE_JvWcC&printsec=frontcover&hl=de&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=true (Accessed: 16 April 2012)

**Orissa Tourism (2012)** *Climate in Odisha (Orissa)*. Available at: http://www.orissa tourism.org/climate-in-orissa.html (Accessed: 22 April 2012)

**OWDM (2011)** *Promoting livelihoods through rice production*, available at: http://www.orissawatershed.org/admin/Publication/Publication_55.pdf (Accessed: 03 June 2012)

**Pauss, A., Naveau, H. and Nyns, E.J. (1987)** *Biogas Production*. In: Hall, D.O. and Overend, R.P. (1987) *Biomass*. Wiley & Sons Ltd, Great Britain.

**Plöchl, M. and Heiermann, M. (2006)** *Biogas Farming in Central and Northern Europe: A Strategy for Developing Countries?*. Available at: http://ecommons.library .cornell.edu/bitstream/1813/10559/1/Invited%20Overview%20Plochl%20final%202 7Feb2006.pdf (Accessed: 31 May 2012)

**Pollio, G. (1999)** *International Project Analysis and Financing.* Macmillan Press Ltd., London.

**Planning Commission Government of India (2002)** *Evaluation Study on National Project on Biogas Development*. Available at: http://planningcommission.nic.in/reports/peoreport/peoevalu/peo_npbd.pdf (Accessed: 06 June 2012)

**Planning Commission Government of India (2008a)** *Eleventh Five Year Plan: 2007 – 12*, *Volume III: Agriculture, rural development, industry, services and physical infrastructure.* Available at: http://planningcommission.nic.in/plans/planrel/fiveyr/11th/11_v3/11th_vol3.pdf (Accessed: 01 April 2012)

**Planning Commission Government of India (2008b)** *Eleventh Five Year Plan: 2007 – 12*, *Volume I: Inclusive growth.* Available at: http://planningcommission.nic.in/plans/planrel/fiveyr/11th/11_v1/11th_vol1.pdf (Accessed: 01 April 2012)

**Rao, P.S.C., Miller, J.B., Wang, Y.D. and Byrne, J.B. (2009)** 'Energy-microfinance intervention for below poverty line households in India', *Elsevier*, 37, pp.1694-1712, ScienceDirect [Online]. Available at: http://www.sciencedirect.com/science/article/pii/S0301421509000056 (Accessed: 10 May 2012)

**Ravindranath, N.H. and Chanakya, H.N. (1986)** *Biomass Based Energy Systems for a South Indian Village*. Available at: http://www.sciencedirect.com/science/article/pii/0144456586900910 (Accessed: 01 April 2012)

**RBI (2011)** Malegam, YH: *Report of the Sub-Committee of the Central Board of Directors of Reserve Bank of India to Study Issues and Concerns in the MFI Sector*, Reserve Bank of India, Mumbai. Available at: http://rbidocs.rbi.org.in/rdocs/PublicationReport/Pdfs/YHMR190111.pdf (Accessed 11 May 2012)

**Reddy, A.K.N. and Ravindranath, N.H. (1987)** *Biomass, Village Energy and Rural Development*, in: Hall DO & Overend RP (1987) *Biomass*, Wiley & Sons Ltd, Great Britain.

**Rubab, S. and Kandpal, T.C. (1995)** 'A methodology for financial evaluation of biogas technology in India using cost functions', *Biomass and Bioenergy*, Vol. 10, Issue 1, pp. 11–23. Available at: http://www.sciencedirect.com/science/article /pii/096195349 5000518 (Accessed: 14 April 2012)

**Schweiger, S.G., Armistead, T. F. and Samudrala, S. (2010)** *India energy handbook 2011*. Available at: http://indiaenvironmentportal.org.in/files/India_Energy_ Hand book.pdf (Accessed: 14 April 2012)

**Sinha, G.N. (2008)** *International Energy Law and India*, in: Patel, BN (2008) *India and International Law*, 2nd edition. Available at: http://www.nijhoffonline.nl/ book?id=nij9789004161528_nij9789004161528_i-570 (Accessed: 01 April 2012)

**Stowe, J., Robinson, T., Pinto, J. and McLeavy, D. (2007)** *Equity Asset Valuation.* John Wiley & Sons, Inc., New Jersey.

**Sundaresan, S. (2008)** *Microfinance: Emerging Trends and Challenges.* Edward Elgar Publishing, Cheltenham

**TERI (2006)** *Competition in India's energy sector*. Available at: http://www.cci. gov.in/images/workshop/17-18/17ajoy.pdf (Accessed: 01 April 2012)

**Times of India (2012)** *How to register an NGO*. Available at: http://articles.timesofindia.indiatimes.com/2012-04-04/goa/31287190_1_registration-fee-ngos-mahila-mandals (Accessed 29 May 2009)

**Trading Economics (2012)** *India inflation rate.* Available at: http://www.tradinge conomics.com/india/inflation-cpi (Accessed: 31 May 2012)

**Unicef (2011)** *Indoor air pollution: a case for change.* Available at: http://www. unicef.org/india/Policy_Brief_1-Indoor_air_pollution.pdf (Accessed: 01 June 2012)

**United Nations Development Programme (2011)** *Human development statistical annex.* Available at: http://hdr.undp.org/en/media/HDR_2011_EN_Tables.pdf (Accessed: 14 May 2012)

**USIG (2012a)** *Country Information - India.* Available at: http://www.usig.org/ countryinfo/india.asp (Accessed: 29 May 2012)

**USIG (2012b)** *The Societies Registration Act 1860*. Available at: http://www.usig.org/countryinfo/laws/India/India%20Societies%20Registration%20 Act.pdf (Accessed: 29 May 2012)

**Vasudeo, G. (2004)** *Biogas Manure: a viable input in sustainable agriculture – an integrated approach*. Available at: http://unapcaem.org/Activities%20Files/A01/Bio gas%20Manure%20%28BgM%29%20%20a%20viable%20input%20in%20sustaina ble%20agriculture%20%E2%80%93%20an%20integrated%20approach.pdf (Ac-cessed: 20 June 2012)

**World Bank (2010a)** *Analysis of Models for Improving Rural Electricity Services in India through Distributed Generation and Supply of Renewable Energy*. Available at: http://online.wsj.com/public/resources/documents/WorldBankreport0215.pdf (Accessed: 14 April 2012)

**World Bank (2010b)** *Unleashing the Potential of Renewable Energy in India. A*vailable at: http://siteresources.worldbank.org/EXTENERGY2/Resources /Unleashing _potential_ of_renewables_in_India.pdf (Accessed: 14 April 2012)

**World Bank (2011)** *India Economic Update.* Available at: http://siteresources.worldbank.org/INDIAEXTN/Resources/Reports-Publications/IndiaEconomicUpdate-September2011.pdf (Accessed: 10 May 2012)

**World Health Organization (2011)** *Global Tuberculosis control.* Available at: http://whqlibdoc.who.int/publications/2011/9789241564380_eng.pdf (Accessed: 12 June 2012)

**World travel & tourism council (2012)** *Travel & Tourism – Economic impact 2012*. Available at: http://www.wttc.org/site_media/uploads/downloads/india2012. pdf (Accessed: 10 May 2012)

**Yaron, J. (1994)** in: The World Bank Research Observer (1994) *What makes rural finance institutions successful?* Available at: http://www-wds.worldbank.org /external/default/WDSContentServer/WDSP/IB/1999/09/30/000178830_981019114 51891/Rendered/PDF/multi_page.pdf (Accessed: 29 May 2012)

**Zegst, R. (2002)** *Interest Rate Management*. Berlin: Springer

# Appendices

## Appendix A: Description of the NGO Gram Vikas

Gram Vikas was founded in 1979 and currently operates in the Indian states of Orissa, Madhya Pradesh, Jharkhand, and Andhra Pradesh. Gram Vikas is well represented in the state of Orissa with its head office in Mohuda Village near Berhampur, Orissa. Additionally, the NGO has 25 field offices throughout the state and currently employs 424 people as of March 2011 (Gram Vikas, 2011).

The founding NGO Gram Vikas was registered under the Indian Societies Registration Act of 1860 on January 22, 1979 (Gram Vikas 2012a). This act can be implemented in all states of India. Any organization registered under the above stated act is a society with any charitable purpose. Moreover, any profits remaining at the end of the operating year shall not be spread to its members in any form if registered under the Indian Societies Registration Act of 1860 (USIG 2012b; Times of India, 2012).

Gram Vikas states that its mission is "[t]o promote processes which are sustainable, socially inclusive, and gender equitable; to enable critical masses of poor and marginalised rural people to achieve a dignified quality of life" (Gram Vikas, 2011, p.4). In order to allow people to achieve a dignified quality of life Gram Vikas supports projects that improve community and family infrastructure and enable access to energy sources. Moreover, it promotes sustainable use of natural resources, enables "[...] access to basic education, protected water supply, [and to] sanitation and adequate health services" (Gram Vikas 2011, p.4). Support of Self Help Groups (SHG) by providing "[…] basic record keeping and financial training […]" as well as linking them to local banks for microloans is also given (Gram Vikas 2012c).

The NGO started installing biogas plants in the state Orissa in 1986 and withdrew from this field in 1995-96 (Gram Vikas, 2012b). During the period of biogas plant installations, Gram Vikas provided over 54,000 plants to nearly 6000 rural communities in Orissa. Most of those plants were installed between 1986-92, and held a capacity of two to three $m^3$ qualifying as family size plants. The projects were mainly supported through the National Project on Biogas Development, which was launched under the Ministry of Non-Conventional Energy Sources in 1981-82 (Planning Commission Government of India, 2002). Besides the installation of biogas plants, Gram Vikas has promoted the installation of gravity flow water supplies, smokeless chullahs – a traditional stove, solar applications, and micro-hydro projects (Gram Vikas 2012b).

## Appendix B: India inflation rate

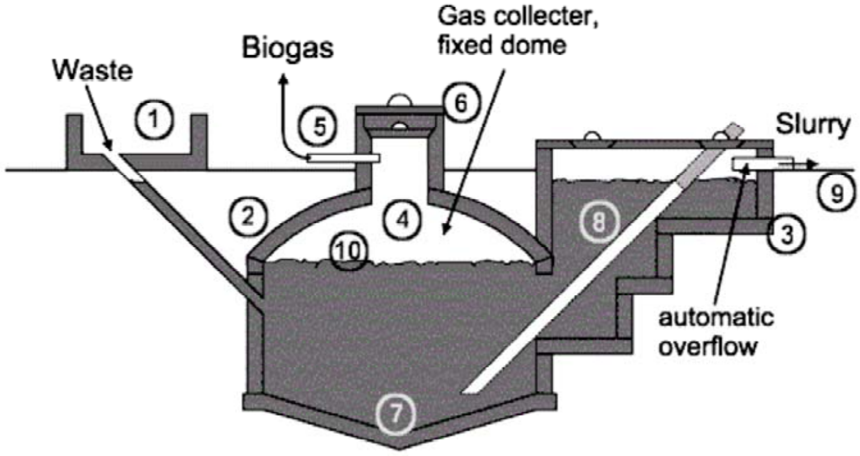
| % | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 6.97 | 9.21 | | | 5.42 | 13.71 | 13.07 | 8 | 8.64 | 9.47 | 9.69 | 10.41 | 6.29 | 15.32 | 0 | 3.23 | 5.21 | 3.96 | 2.86 | 4.63 | 5.31 | 6.72 | 5.51 | 9.7 | 14.97 | 9.47 | 7.5 |
| Feb | 8.21 | 9.38 | 9.45 | 8.03 | 5.45 | 16.09 | 12.87 | 5.7 | 9.13 | 9.89 | 9 | 11.11 | 9.71 | 9.38 | 2.2 | 3.23 | 5.21 | 2.97 | 4.81 | 4.59 | 4.39 | 6.72 | 5.51 | 10.45 | 16.22 | 9.3 | 6.6 |
| Mrz | 8.87 | 8.37 | 9.18 | 8.6 | 6.06 | 15.43 | 13.37 | 5.24 | 9.96 | 9.81 | 8.59 | 10.76 | 9.14 | 8.64 | 3.33 | 3.23 | 5.21 | 3.96 | 3.81 | 3.67 | 5.31 | 7.56 | 5.47 | 9.63 | 14.86 | 8.82 | 6.95 |
| Apr | 8.25 | 7.52 | 9.77 | 8.68 | 6.63 | 13.56 | 13.93 | 6.11 | 9.88 | 9.74 | 8.87 | 10.03 | 8.26 | 8.95 | 5.62 | 2.13 | 5.21 | 3.96 | 3.81 | 3.67 | 5.31 | 6.72 | 7.87 | 8.03 | 14.86 | 8.82 | 6.89 |
| Mai | 8.5 | 7.47 | 10.42 | 7.9 | 7.78 | 12.22 | 14.36 | 6.06 | 9.8 | 9.67 | 9.83 | 9.26 | 8.19 | 8.36 | 5.56 | 2.11 | 4.12 | 4.95 | 2.83 | 4.59 | 5.26 | 6.67 | 7.81 | 8.7 | 13.33 | 9.41 | 7.23 |
| Jun | 8.53 | 7.99 | 9.67 | 8.06 | 7.69 | 12.09 | 14.71 | 5.13 | 10.57 | 10.29 | 9.33 | 7.32 | 10.51 | 7.71 | 5.56 | 2.11 | 5.15 | 4.9 | 2.8 | 3.64 | 6.14 | 6.61 | 7.75 | 8.63 | 13.91 | 8.72 | |
| Jul | 8.58 | 8.66 | 9.37 | 7.17 | 8.82 | 12.97 | 12.92 | 5.93 | 10.8 | 10.47 | 8.82 | 6.61 | 12.39 | 5.26 | 4.4 | 4.21 | 4.04 | 3.88 | 3.74 | 2.7 | 7.89 | 5.69 | 7.69 | 9.29 | 13.73 | 8.62 | |
| Aug | 8.62 | 8.38 | 9.81 | 6.66 | 9.88 | 13.23 | 13.08 | 4.55 | 11.07 | 11.39 | 8.31 | 5.6 | 14.8 | 3.16 | 4.35 | 4.17 | 4 | 3.85 | 3.7 | 3.57 | 6.9 | 6.45 | 8.33 | 11.89 | 11.25 | 8.43 | |
| Sep | 8.74 | 9.52 | 8.7 | 7.23 | 9.2 | 14.21 | 11.52 | 5.79 | 10.94 | 10.92 | 8.89 | 4.66 | 15.04 | 3.37 | 4.35 | 5.21 | 3.96 | 2.86 | 4.63 | 3.54 | 5.98 | 7.26 | 9.02 | 11.72 | 9.88 | 8.99 | |
| Okt | 9.21 | 10.21 | 8.19 | 7.65 | 8.52 | 15.71 | 9.95 | 6.58 | 11.2 | 10.07 | 8.52 | 4.94 | 16.34 | 2.2 | 3.23 | 4.17 | 5 | 2.86 | 4.63 | 3.54 | 6.84 | 6.4 | 9.77 | 11.64 | 9.82 | 9.72 | |
| Nov | 9.6 | 9.49 | 9.77 | 5.39 | 10.8 | 14.36 | 9.42 | 7.38 | 10.31 | 10.38 | 8.46 | 5.49 | 18.63 | 0 | 3.19 | 4.12 | 3.96 | 3.81 | 4.59 | 3.51 | 7.63 | 5.51 | 10.45 | 11.49 | 9.7 | 9.73 | |
| Dez | 9.84 | 9.1 | 9.7 | 4.76 | 12.5 | 13.64 | 8.44 | 8.61 | 9.81 | 10.31 | 8.72 | 4.87 | 19.67 | 0 | 2.11 | 5.15 | 3.92 | 2.83 | 3.67 | 5.31 | 6.72 | 5.51 | 10.45 | 13.51 | 8.33 | 9.1 | |
| | **8.66** | **8.735** | **9.457** | **7.285** | **7.778** | **13.94** | **12.3** | **6.257** | **10.18** | **10.2** | **8.919** | **7.588** | **12.41** | **6.029** | **3.658** | **3.589** | **4.583** | **3.733** | **3.823** | **3.913** | **6.14** | **6.485** | **7.969** | **10.39** | **12.57** | **9.094** | **7.034** |

Average from 1996 to 2011: 6.93%

*(The average of the last 15 years is chosen to estimate average inflation for the future 15 years, which is equal to the project's lifetime.)*

Source: Trading Economics (2012)

## Appendix C: Fixed dome biogas plant system




1. Mixing tank with inlet pipe and sand trap, 2. Digester. 3. Compensation and removal tank. 4. Gas-holder. 5. Gaspipe. 6. Entry hatch, with gastight seal. 7. Accumulation of thick sludge. 8. Outlet pipe. 9. Reference level. 10. Supernatant scum, broken up by varying level.

Source: Kossmann, Poenits and Habermehl (1997b)

## Appendix D: The State Orissa, India


Source: Orissa Tourism (2012)

## Appendix E: Construction time biogas plant

| Activity | Days |
|---|---|
| Selection of Site | 1 |
| Marking of Layout | |
| Digging of Pit | |
| Laying of Foundation | 1 |
| Digester construction | 4 |
| Construction of outlet chamber in Deenbandhu model | |
| Fixation of guide frame in case of floating drum KVIC or Pragati Model | |
| Plastering | 2 |
| Curing of construction | 5 |
| Laying of gas distribution pipeline, fixing accessories, ect. | |
| Slurry making to fill the digestor | 2 |
| Testing for gas leakages | 1 |

Source: Acara (2012)

15 days construction time – 5 days curing results in 10 days for working on site

# Appendix F: Economic Viability of Scenario 1

## *Balance Sheet*

| **Period** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Assets** | | | | | | | | | | | | | | | | |
| Cash | 633,514 | 875,106 | 1,147,215 | 1,453,631 | 1,798,615 | 2,186,966 | 2,211,408 | 2,237,850 | 2,266,431 | 2,297,300 | 2,330,614 | 2,366,544 | 2,405,270 | 2,446,987 | 2,491,901 | 2,540,235 |
| Accounts receivable | | 1,270,655 | 1,007,434 | 710,829 | 376,609 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Inventories | 649,275 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Assets** | **1,282,789** | **2,145,761** | **2,154,649** | **2,164,460** | **2,175,224** | **2,186,966** | **2,211,408** | **2,237,850** | **2,266,431** | **2,297,300** | **2,330,614** | **2,366,544** | **2,405,270** | **2,446,987** | **2,491,901** | **2,540,235** |
| **Equity and Liabilities** | | | | | | | | | | | | | | | | |
| Total equity | 1,282,789 | 2,145,761 | 2,154,649 | 2,164,460 | 2,175,224 | 2,186,966 | 2,211,408 | 2,237,850 | 2,266,431 | 2,297,300 | 2,330,614 | 2,366,544 | 2,405,270 | 2,446,987 | 2,491,901 | 2,540,235 |
| *Capital stock* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* |
| *Profit/Loss of the year* | *-317,211* | *862,971* | *8,888* | *9,811* | *10,764* | *11,742* | *24,442* | *26,442* | *28,581* | *30,868* | *33,314* | *35,930* | *38,726* | *41,717* | *44,915* | *48,334* |
| *Accumulated profit/loss* | | *-317,211* | *545,761* | *554,649* | *564,460* | *575,224* | *586,966* | *611,408* | *637,850* | *666,431* | *697,300* | *730,614* | *766,544* | *805,270* | *846,987* | *891,901* |
| Liabilities | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Equiy and Liabilities** | **1,282,789** | **2,145,761** | **2,154,649** | **2,164,460** | **2,175,224** | **2,186,966** | **2,211,408** | **2,237,850** | **2,266,431** | **2,297,300** | **2,330,614** | **2,366,544** | **2,405,270** | **2,446,987** | **2,491,901** | **2,540,235** |

## *Profit and Loss Statement*

| **Period** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Revenue | 0.00 | 1,586,750.00 | 88,218.28 | 94,332.91 | 100,871.36 | 107,863.01 | 115,339.26 | 123,333.71 | 131,882.28 | 141,023.37 | 150,798.06 | 161,250.25 | 172,426.90 | 184,378.24 | 197,157.96 | 210,823.47 |
| CoGS | -301,510.00 | -711,131.67 | -66,144.11 | -70,728.72 | -75,631.10 | -80,873.29 | -86,478.82 | -92,472.88 | -98,882.40 | -105,736.19 | -113,065.03 | -120,901.85 | -129,281.86 | -138,242.71 | -147,824.66 | -158,070.75 |
| **Gross Profit** | **-301,510.00** | **875,618.33** | **22,074.17** | **23,604.19** | **25,240.26** | **26,989.72** | **28,860.45** | **30,860.84** | **32,999.88** | **35,287.18** | **37,733.02** | **40,348.39** | **43,145.04** | **46,135.53** | **49,333.30** | **52,752.72** |
| SG&A | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 |
| **EBITDA** | **-317,210.61** | **859,917.72** | **6,373.57** | **7,903.58** | **9,539.65** | **11,289.11** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Depr./Amort. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **EBIT** | **-317,210.61** | **859,917.72** | **6,373.57** | **7,903.58** | **9,539.65** | **11,289.11** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Financial income (interest) | 0.00 | 3,053.44 | 2,514.79 | 1,907.83 | 1,223.88 | 453.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **EBT** | **-317,210.61** | **862,971.16** | **8,888.35** | **9,811.41** | **10,763.53** | **11,742.31** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Tax expenses | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Net income** | **-317,210.61** | **862,971.16** | **8,888.35** | **9,811.41** | **10,763.53** | **11,742.31** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |

### *FCFE and NPV Calculation*

| Period | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Net income | -317,210.61 | 862,971.16 | 8,888.35 | 9,811.41 | 10,763.53 | 11,742.31 | 24,441.71 | 26,442.10 | 28,581.14 | 30,868.45 | 33,314.29 | 35,929.66 | 38,726.31 | 41,716.80 | 44,914.57 | 48,333.98 |
| Depreciation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Investment in fixed assets | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Investment in Working Capital | -649,275.00 | -621,379.65 | 263,221.09 | 296,604.11 | 334,220.94 | 376,608.52 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Net borrowing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **FCFE** | **-966,485.61** | **241,591.51** | **272,109.44** | **306,415.52** | **344,984.47** | **388,350.83** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| **PV of FCFE** | **-966,485.61** | **206,453.18** | **198,711.69** | **191,218.75** | **183,975.15** | **176,979.83** | **9,518.56** | **8,799.85** | **8,128.28** | **7,501.95** | **6,918.78** | **6,376.64** | **5,873.34** | **5,406.67** | **4,974.46** | **4,574.58** |

| | |
|---|---|
| **NPV** | **58,926.10** |

# Appendix G: Economic Viability of Scenario 2

### *Balance Sheet*

| Period | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Assets** | | | | | | | | | | | | | | | | |
| Cash | 1,041,902 | 1,606,605 | 1,750,726 | 1,912,009 | 2,092,544 | 2,294,916 | 2,319,357 | 2,345,800 | 2,374,381 | 2,405,249 | 2,438,563 | 2,474,493 | 2,513,219 | 2,554,936 | 2,599,851 | 2,648,185 |
| Accounts receivable | | 606,058 | 480,511 | 339,041 | 179,629 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Inventories | 649,275 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Assets** | **1,691,177** | **2,212,663** | **2,231,237** | **2,251,050** | **2,272,173** | **2,294,916** | **2,319,357** | **2,345,800** | **2,374,381** | **2,405,249** | **2,438,563** | **2,474,493** | **2,513,219** | **2,554,936** | **2,599,851** | **2,648,185** |
| **Equity and Liabilities** | | | | | | | | | | | | | | | | |
| Total equity | 1,691,177 | 2,212,663 | 2,231,237 | 2,251,050 | 2,272,173 | 2,294,916 | 2,319,357 | 2,345,800 | 2,374,381 | 2,405,249 | 2,438,563 | 2,474,493 | 2,513,219 | 2,554,936 | 2,599,851 | 2,648,185 |
| *Capital stock* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* | *1,600,000* |
| *Profit/Loss of the year* | *91,177* | *521,487* | *18,573* | *19,814* | *21,123* | *22,742* | *24,442* | *26,442* | *28,581* | *30,868* | *33,314* | *35,930* | *38,726* | *41,717* | *44,915* | *48,334* |
| *Accumulated profit/loss* | | *91,177* | *612,663* | *631,237* | *651,050* | *672,173* | *694,916* | *719,357* | *745,800* | *774,381* | *805,249* | *838,563* | *874,493* | *913,219* | *954,936* | *999,851* |
| Liabilities | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Equiy and Liabilities** | **1,691,177** | **2,212,663** | **2,231,237** | **2,251,050** | **2,272,173** | **2,294,916** | **2,319,357** | **2,345,800** | **2,374,381** | **2,405,249** | **2,438,563** | **2,474,493** | **2,513,219** | **2,554,936** | **2,599,851** | **2,648,185** |

## *Profit and Loss Statement*

| **Period** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Revenue | 408,387.50 | 1,246,862.50 | 99,218.28 | 105,332.91 | 111,871.36 | 118,863.01 | 115,339.26 | 123,333.71 | 131,882.28 | 141,023.37 | 150,798.06 | 161,250.25 | 172,426.90 | 184,378.24 | 197,157.96 | 210,823.47 |
| CoGS | -301,510.00 | -711,131.67 | -66,144.11 | -70,728.72 | -75,631.10 | -80,873.29 | -86,478.82 | -92,472.88 | -98,882.40 | -105,736.19 | -113,065.03 | -120,901.85 | -129,281.86 | -138,242.71 | -147,824.66 | -158,070.75 |
| **Gross Profit** | **106,877.50** | **535,730.83** | **33,074.17** | **34,604.19** | **36,240.26** | **37,989.72** | **28,860.45** | **30,860.84** | **32,999.88** | **35,287.18** | **37,733.02** | **40,348.39** | **43,145.04** | **46,135.53** | **49,333.30** | **52,752.72** |
| SG&A | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 |
| **EBITDA** | **91,176.89** | **520,030.22** | **17,373.57** | **18,903.58** | **20,539.65** | **22,289.11** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Depr./Amort. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **EBIT** | **91,176.89** | **520,030.22** | **17,373.57** | **18,903.58** | **20,539.65** | **22,289.11** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Financial income (interest) | 0.00 | 1,456.38 | 1,199.47 | 909.97 | 583.75 | 453.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **EBT** | **91,176.89** | **521,486.61** | **18,573.03** | **19,813.55** | **21,123.40** | **22,742.31** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Tax expenses | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Net income** | **91,176.89** | **521,486.61** | **18,573.03** | **19,813.55** | **21,123.40** | **22,742.31** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |

## *FCFE and NPV Calculation*

| **Period** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Net income | 91,176.89 | 521,486.61 | 18,573.03 | 19,813.55 | 21,123.40 | 22,742.31 | 24,441.71 | 26,442.10 | 28,581.14 | 30,868.45 | 33,314.29 | 35,929.66 | 38,726.31 | 41,716.80 | 44,914.57 | 48,333.98 |
| Depreciation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Investment in fixed assets | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Investment in Working Capital | -649,275.00 | 43,216.87 | 125,547.32 | 141,469.86 | 159,411.78 | 179,629.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Net borrowing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **FCFE** | **-558,098.11** | **564,703.48** | **144,120.35** | **161,283.41** | **180,535.17** | **202,371.49** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| **PV of FCFE** | **-558,098.11** | **482,570.05** | **105,245.88** | **100,648.99** | **96,276.76** | **92,225.04** | **9,518.56** | **8,799.85** | **8,128.28** | **7,501.95** | **6,918.78** | **6,376.64** | **5,873.34** | **5,406.67** | **4,974.46** | **4,574.58** |

| | |
|---|---|
| **NPV** | **386,941.72** |

# Appendix H: Economic Viability of Scenario 3

## *Balance Sheet*

| **Period** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Assets** | | | | | | | | | | | | | | | | |
| Cash | 633,514 | 671,622 | 740,247 | 843,179 | 984,679 | 1,169,546 | 990,504 | 813,462 | 842,043 | 872,911 | 906,225 | 942,155 | 980,881 | 1,022,598 | 1,067,513 | 1,115,847 |
| Accounts receivable | 0 | 1,270,655 | 1,007,434 | 710,829 | 376,609 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Inventories | 649,275 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Assets** | **1,282,789** | **1,942,276** | **1,747,681** | **1,554,008** | **1,361,288** | **1,169,546** | **990,504** | **813,462** | **842,043** | **872,911** | **906,225** | **942,155** | **980,881** | **1,022,598** | **1,067,513** | **1,115,847** |
| **Equity and Liabilities** | | | | | | | | | | | | | | | | |
| Total equity | 162,789 | 950,912 | 894,213 | 848,363 | 814,106 | 792,236 | 795,294 | 813,462 | 842,043 | 872,911 | 906,225 | 942,155 | 980,881 | 1,022,598 | 1,067,513 | 1,115,847 |
| *Capital stock* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* |
| *Profit/Loss of the year* | *-317,211* | *788,123* | *-56,700* | *-45,850* | *-34,256* | *-21,870* | *3,058* | *18,167* | *28,581* | *30,868* | *33,314* | *35,930* | *38,726* | *41,717* | *44,915* | *48,334* |
| *Accumulated profit/loss* | | *-317,211* | *470,912* | *414,213* | *368,363* | *334,106* | *312,236* | *315,294* | *333,462* | *362,043* | *392,911* | *426,225* | *462,155* | *500,881* | *542,598* | *587,513* |
| Liabilities | 1,120,000 | 991,364 | 853,468 | 705,645 | 547,181 | 377,310 | 195,209 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Equiy and Liabilities** | **1,282,789** | **1,942,276** | **1,747,681** | **1,554,008** | **1,361,288** | **1,169,546** | **990,504** | **813,462** | **842,043** | **872,911** | **906,225** | **942,155** | **980,881** | **1,022,598** | **1,067,513** | **1,115,847** |

## *Profit and Loss Statement*

| **Period** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Revenue | 0.00 | 1,586,750.00 | 88,218.28 | 94,332.91 | 100,871.36 | 107,863.01 | 115,339.26 | 123,333.71 | 131,882.28 | 141,023.37 | 150,798.06 | 161,250.25 | 172,426.90 | 184,378.24 | 197,157.96 | 210,823.47 |
| CoGS | -301,510.00 | -711,131.67 | -66,144.11 | -70,728.72 | -75,631.10 | -80,873.29 | -86,478.82 | -92,472.88 | -98,882.40 | -105,736.19 | -113,065.03 | -120,901.85 | -129,281.86 | -138,242.71 | -147,824.66 | -158,070.75 |
| **Gross Profit** | **-301,510.00** | **875,618.33** | **22,074.17** | **23,604.19** | **25,240.26** | **26,989.72** | **28,860.45** | **30,860.84** | **32,999.88** | **35,287.18** | **37,733.02** | **40,348.39** | **43,145.04** | **46,135.53** | **49,333.30** | **52,752.72** |
| SG&A | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 |
| **EBITDA** | **-317,210.61** | **859,917.72** | **6,373.57** | **7,903.58** | **9,539.65** | **11,289.11** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Depr./Amort. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **EBIT** | **-317,210.61** | **859,917.72** | **6,373.57** | **7,903.58** | **9,539.65** | **11,289.11** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Financial income (interest) | 0.00 | -71,794.83 | -63,073.29 | -53,753.45 | -43,795.98 | -33,159.20 | -21,383.75 | -8,274.77 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **EBT** | **-317,210.61** | **788,122.89** | **-56,699.73** | **-45,849.87** | **-34,256.34** | **-21,870.09** | **3,057.97** | **18,167.33** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Tax expenses | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Net income** | **-317,210.61** | **788,122.89** | **-56,699.73** | **-45,849.87** | **-34,256.34** | **-21,870.09** | **3,057.97** | **18,167.33** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |

## *FCFE and NPV Calculation*

| Period | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Net income | -317,210.61 | 788,122.89 | -56,699.73 | -45,849.87 | -34,256.34 | -21,870.09 | 3,057.97 | 18,167.33 | 28,581.14 | 30,868.45 | 33,314.29 | 35,929.66 | 38,726.31 | 41,716.80 | 44,914.57 | 48,333.98 |
| Depreciation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Investment in fixed assets | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Investment in Working Capital | -649,275.00 | -621,379.65 | 263,221.09 | 296,604.11 | 334,220.94 | 376,608.52 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Net borrowing | 1,120,000.00 | -128,635.79 | -137,895.98 | -147,822.78 | -158,464.19 | -169,871.66 | -182,100.31 | -195,209.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **FCFE** | **153,514.39** | **38,107.45** | **68,625.38** | **102,931.46** | **141,500.41** | **184,866.77** | **-179,042.35** | **-177,041.96** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| **PV of FCFE** | **153,514.39** | **32,564.91** | **50,114.64** | **64,234.42** | **75,460.09** | **84,247.76** | **-69,726.07** | **-58,919.02** | **8,128.28** | **7,501.95** | **6,918.78** | **6,376.64** | **5,873.34** | **5,406.67** | **4,974.46** | **4,574.58** |

| | |
|---|---|
| **NPV** | **381,245.81** |

# Appendix I: Economic Viability of Scenario 4

## *Balance Sheet*

| Period | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Assets** | | | | | | | | | | | | | | | | |
| Cash | 1,041,902 | 1,403,121 | 1,343,758 | 1,301,557 | 1,278,608 | 1,277,495 | 1,098,453 | 921,411 | 949,992 | 980,861 | 1,014,175 | 1,050,105 | 1,088,831 | 1,130,548 | 1,175,462 | 1,223,796 |
| Accounts receivable | 0 | 606,058 | 480,511 | 339,041 | 179,629 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Inventories | 649,275 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Assets** | **1,691,177** | **2,009,179** | **1,824,268** | **1,640,598** | **1,458,237** | **1,277,495** | **1,098,453** | **921,411** | **949,992** | **980,861** | **1,014,175** | **1,050,105** | **1,088,831** | **1,130,548** | **1,175,462** | **1,223,796** |
| **Equity and Liabilities** | | | | | | | | | | | | | | | | |
| Total equity | 571,177 | 1,017,815 | 970,800 | 934,952 | 911,056 | 900,186 | 903,244 | 921,411 | 949,992 | 980,861 | 1,014,175 | 1,050,105 | 1,088,831 | 1,130,548 | 1,175,462 | 1,223,796 |
| *Capital stock* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* | *480,000* |
| *Profit/Loss of the year* | *91,177* | *446,638* | *-47,015* | *-35,848* | *-23,896* | *-10,870* | *3,058* | *18,167* | *28,581* | *30,868* | *33,314* | *35,930* | *38,726* | *41,717* | *44,915* | *48,334* |
| *Accumulated profit/loss* | | *91,177* | *537,815* | *490,800* | *454,952* | *431,056* | *420,186* | *423,244* | *441,411* | *469,992* | *500,861* | *534,175* | *570,105* | *608,831* | *650,548* | *695,462* |
| Liabilities | 1,120,000 | 991,364 | 853,468 | 705,645 | 547,181 | 377,310 | 195,209 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Equiy and Liabilities** | **1,691,177** | **2,009,179** | **1,824,268** | **1,640,598** | **1,458,237** | **1,277,495** | **1,098,453** | **921,411** | **949,992** | **980,861** | **1,014,175** | **1,050,105** | **1,088,831** | **1,130,548** | **1,175,462** | **1,223,796** |

## *Profit and Loss Statement*

| **Period** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Revenue | 408,387.50 | 1,246,862.50 | 99,218.28 | 105,332.91 | 111,871.36 | 118,863.01 | 115,339.26 | 123,333.71 | 131,882.28 | 141,023.37 | 150,798.06 | 161,250.25 | 172,426.90 | 184,378.24 | 197,157.96 | 210,823.47 |
| CoGS | -301,510.00 | -711,131.67 | -66,144.11 | -70,728.72 | -75,631.10 | -80,873.29 | -86,478.82 | -92,472.88 | -98,882.40 | -105,736.19 | -113,065.03 | -120,901.85 | -129,281.86 | -138,242.71 | -147,824.66 | -158,070.75 |
| **Gross Profit** | **106,877.50** | **535,730.83** | **33,074.17** | **34,604.19** | **36,240.26** | **37,989.72** | **28,860.45** | **30,860.84** | **32,999.88** | **35,287.18** | **37,733.02** | **40,348.39** | **43,145.04** | **46,135.53** | **49,333.30** | **52,752.72** |
| SG&A | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -15,700.61 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 | -4,418.73 |
| **EBITDA** | **91,176.89** | **520,030.22** | **17,373.57** | **18,903.58** | **20,539.65** | **22,289.11** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Depr./Amort. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **EBIT** | **91,176.89** | **520,030.22** | **17,373.57** | **18,903.58** | **20,539.65** | **22,289.11** | **24,441.71** | **26,442.10** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Financial income (interest) | 0.00 | -73,391.88 | -64,388.62 | -54,751.31 | -44,436.12 | -33,159.20 | -21,383.75 | -8,274.77 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **EBT** | **91,176.89** | **446,638.34** | **-47,015.05** | **-35,847.73** | **-23,896.47** | **-10,870.09** | **3,057.97** | **18,167.33** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| Tax expenses | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Net income** | **91,176.89** | **446,638.34** | **-47,015.05** | **-35,847.73** | **-23,896.47** | **-10,870.09** | **3,057.97** | **18,167.33** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |

## *FCFE and NPV Calculation*

| **Period** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Net income | 91,176.89 | 446,638.34 | -47,015.05 | -35,847.73 | -23,896.47 | -10,870.09 | 3,057.97 | 18,167.33 | 28,581.14 | 30,868.45 | 33,314.29 | 35,929.66 | 38,726.31 | 41,716.80 | 44,914.57 | 48,333.98 |
| Depreciation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Investment in fixed assets | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Investment in Working Capital | -649,275.00 | 43,216.87 | 125,547.32 | 141,469.86 | 159,411.78 | 179,629.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Net borrowing | 1,120,000.00 | -128,635.79 | -137,895.98 | -147,822.78 | -158,464.19 | -169,871.66 | -182,100.31 | -195,209.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **FCFE** | **561,901.89** | **361,219.42** | **-59,363.71** | **-42,200.65** | **-22,948.89** | **-1,112.57** | **-179,042.35** | **-177,041.96** | **28,581.14** | **30,868.45** | **33,314.29** | **35,929.66** | **38,726.31** | **41,716.80** | **44,914.57** | **48,333.98** |
| **PV of FCFE** | **561,901.89** | **308,681.78** | **-43,351.17** | **-26,335.34** | **-12,238.30** | **-507.02** | **-69,726.07** | **-58,919.02** | **8,128.28** | **7,501.95** | **6,918.78** | **6,376.64** | **5,873.34** | **5,406.67** | **4,974.46** | **4,574.58** |

| | |
|---|---|
| **NPV** | **709,261.43** |

## Appendix J: Calculation of the effective nominal interest rate of the RIDF loan to the project company

$$Effective\ Nominal\ Interest\ Rate\ p.a. = \left[1 + \frac{i}{m}\right]^{m} - 1$$

(i = nominal interest rate p.a., m = n repayment periods within one year)

In the case of the RIDF loan to the project company:

$$Effective\ Nominal\ Interest\ Rate\ p.a. = \left[1 + \frac{0.07}{m5}\right]^{5} - 1$$

$$Effective\ Nominal\ Interest\ Rate\ p.a. = 7.20\%\ p.a.$$

Source: Brealey, Myers, and Allen, 2011

## Appendix K: Annuity calculation of the RIDF loan to the project company

| year | repayment periods | beginning-of-period balance | period-end interest on balance | total period-end payment | amortization of loan | end-of-period balance |
|---|---|---|---|---|---|---|
| 1 | 1 | 1,120,000.00 | 15680.00 | 40696.81 | 25016.81 | 1,094,983.19 |
| | 2 | 1,094,983.19 | 15329.76 | 40696.81 | 25367.05 | 1,069,616.14 |
| | 3 | 1,069,616.14 | 14974.63 | 40696.81 | 25722.19 | 1,043,893.95 |
| | 4 | 1,043,893.95 | 14614.52 | 40696.81 | 26082.30 | 1,017,811.66 |
| | 5 | 1,017,811.66 | 14249.36 | 40696.81 | 26447.45 | 991,364.21 |
| 2 | 1 | 991,364.21 | 13879.10 | 40696.81 | 26817.71 | 964,546.50 |
| | 2 | 964,546.50 | 13503.65 | 40696.81 | 27193.16 | 937,353.33 |
| | 3 | 937,353.33 | 13122.95 | 40696.81 | 27573.87 | 909,779.47 |
| | 4 | 909,779.47 | 12736.91 | 40696.81 | 27959.90 | 881,819.57 |
| | 5 | 881,819.57 | 12345.47 | 40696.81 | 28351.34 | 853,468.23 |
| 3 | 1 | 853,468.23 | 11948.56 | 40696.81 | 28748.26 | 824,719.98 |
| | 2 | 824,719.98 | 11546.08 | 40696.81 | 29150.73 | 795,569.24 |
| | 3 | 795,569.24 | 11137.97 | 40696.81 | 29558.84 | 766,010.40 |
| | 4 | 766,010.40 | 10724.15 | 40696.81 | 29972.67 | 736,037.73 |
| | 5 | 736,037.73 | 10304.53 | 40696.81 | 30392.28 | 705,645.45 |
| 4 | 1 | 705,645.45 | 9879.04 | 40696.81 | 30817.78 | 674,827.67 |
| | 2 | 674,827.67 | 9447.59 | 40696.81 | 31249.22 | 643,578.45 |
| | 3 | 643,578.45 | 9010.10 | 40696.81 | 31686.71 | 611,891.74 |
| | 4 | 611,891.74 | 8566.48 | 40696.81 | 32130.33 | 579,761.41 |
| | 5 | 579,761.41 | 8116.66 | 40696.81 | 32580.15 | 547,181.26 |
| 5 | 1 | 547,181.26 | 7660.54 | 40696.81 | 33036.27 | 514,144.98 |
| | 2 | 514,144.98 | 7198.03 | 40696.81 | 33498.78 | 480,646.20 |
| | 3 | 480,646.20 | 6729.05 | 40696.81 | 33967.77 | 446,678.43 |
| | 4 | 446,678.43 | 6253.50 | 40696.81 | 34443.31 | 412,235.12 |
| | 5 | 412,235.12 | 5771.29 | 40696.81 | 34925.52 | 377,309.60 |
| 6 | 1 | 377,309.60 | 5282.33 | 40696.81 | 35414.48 | 341,895.12 |
| | 2 | 341,895.12 | 4786.53 | 40696.81 | 35910.28 | 305,984.84 |
| | 3 | 305,984.84 | 4283.79 | 40696.81 | 36413.02 | 269,571.82 |
| | 4 | 269,571.82 | 3774.01 | 40696.81 | 36922.81 | 232,649.01 |
| | 5 | 232,649.01 | 3257.09 | 40696.81 | 37439.73 | 195,209.29 |
| 7 | 1 | 195,209.29 | 2732.93 | 40696.81 | 37963.88 | 157,245.40 |
| | 2 | 157,245.40 | 2201.44 | 40696.81 | 38495.38 | 118,750.03 |
| | 3 | 118,750.03 | 1662.50 | 40696.81 | 39034.31 | 79,715.72 |
| | 4 | 79,715.72 | 1116.02 | 40696.81 | 39580.79 | 40,134.92 |
| | 5 | 40,134.92 | 561.89 | 40696.81 | 40134.92 | 0.00 |

## Appendix L: Calculation of the effective nominal interest rate of the Microloan to Private Households

$$Effective\ Nominal\ Interest\ Rate\ p.a. = \left[1 + \frac{i}{m}\right]^{m} - 1$$

(i = nominal interest rate p.a., m = n repayment periods within one year)

In the case of the microloan to households provided by the project company:

$$Effective\ Nominal\ Interest\ Rate\ p.a. = \left[1 + \frac{0.12}{12}\right]^{12} - 1$$

$$Effective\ Nominal\ Interest\ Rate\ p.a. = 12.68\%\ p.a.$$

Source: Brealey, Myers, and Allen (2011)

# Appendix M: Scenario 1, Annuity calculation of the Microloan to Private Households

| year | repayment periods | beginning-of-period balance | period-end interest on balance | total period-end payment | amortization of loan | end-of-period balance |
|---|---|---|---|---|---|---|
| 1 | 1 | 27,350.00 | 273.50 | 608.39 | 334.89 | 27,015.11 |
| | 2 | 27,015.11 | 270.15 | 608.39 | 338.23 | 26,676.88 |
| | 3 | 26,676.88 | 266.77 | 608.39 | 341.62 | 26,335.26 |
| | 4 | 26,335.26 | 263.35 | 608.39 | 345.03 | 25,990.23 |
| | 5 | 25,990.23 | 259.90 | 608.39 | 348.48 | 25,641.75 |
| | 6 | 25,641.75 | 256.42 | 608.39 | 351.97 | 25,289.78 |
| | 7 | 25,289.78 | 252.90 | 608.39 | 355.49 | 24,934.29 |
| | 8 | 24,934.29 | 249.34 | 608.39 | 359.04 | 24,575.25 |
| | 9 | 24,575.25 | 245.75 | 608.39 | 362.63 | 24,212.61 |
| | 10 | 24,212.61 | 242.13 | 608.39 | 366.26 | 23,846.36 |
| | 11 | 23,846.36 | 238.46 | 608.39 | 369.92 | 23,476.43 |
| | 12 | 23,476.43 | 234.76 | 608.39 | 373.62 | 23,102.81 |
| 2 | 1 | 23,102.81 | 231.03 | 608.39 | 377.36 | 22,725.45 |
| | 2 | 22,725.45 | 227.25 | 608.39 | 381.13 | 22,344.32 |
| | 3 | 22,344.32 | 223.44 | 608.39 | 384.94 | 21,959.38 |
| | 4 | 21,959.38 | 219.59 | 608.39 | 388.79 | 21,570.59 |
| | 5 | 21,570.59 | 215.71 | 608.39 | 392.68 | 21,177.91 |
| | 6 | 21,177.91 | 211.78 | 608.39 | 396.61 | 20,781.30 |
| | 7 | 20,781.30 | 207.81 | 608.39 | 400.57 | 20,380.73 |
| | 8 | 20,380.73 | 203.81 | 608.39 | 404.58 | 19,976.15 |
| | 9 | 19,976.15 | 199.76 | 608.39 | 408.62 | 19,567.53 |
| | 10 | 19,567.53 | 195.68 | 608.39 | 412.71 | 19,154.82 |
| | 11 | 19,154.82 | 191.55 | 608.39 | 416.84 | 18,737.98 |
| | 12 | 18,737.98 | 187.38 | 608.39 | 421.01 | 18,316.97 |
| 3 | 1 | 18,316.97 | 183.17 | 608.39 | 425.22 | 17,891.76 |
| | 2 | 17,891.76 | 178.92 | 608.39 | 429.47 | 17,462.29 |
| | 3 | 17,462.29 | 174.62 | 608.39 | 433.76 | 17,028.53 |
| | 4 | 17,028.53 | 170.29 | 608.39 | 438.10 | 16,590.43 |
| | 5 | 16,590.43 | 165.90 | 608.39 | 442.48 | 16,147.95 |
| | 6 | 16,147.95 | 161.48 | 608.39 | 446.91 | 15,701.04 |
| | 7 | 15,701.04 | 157.01 | 608.39 | 451.38 | 15,249.66 |
| | 8 | 15,249.66 | 152.50 | 608.39 | 455.89 | 14,793.77 |
| | 9 | 14,793.77 | 147.94 | 608.39 | 460.45 | 14,333.33 |
| | 10 | 14,333.33 | 143.33 | 608.39 | 465.05 | 13,868.27 |
| | 11 | 13,868.27 | 138.68 | 608.39 | 469.70 | 13,398.57 |
| | 12 | 13,398.57 | 133.99 | 608.39 | 474.40 | 12,924.17 |
| 4 | 1 | 12,924.17 | 129.24 | 608.39 | 479.14 | 12,445.03 |
| | 2 | 12,445.03 | 124.45 | 608.39 | 483.94 | 11,961.09 |
| | 3 | 11,961.09 | 119.61 | 608.39 | 488.77 | 11,472.32 |
| | 4 | 11,472.32 | 114.72 | 608.39 | 493.66 | 10,978.66 |
| | 5 | 10,978.66 | 109.79 | 608.39 | 498.60 | 10,480.06 |
| | 6 | 10,480.06 | 104.80 | 608.39 | 503.59 | 9,976.47 |
| | 7 | 9,976.47 | 99.76 | 608.39 | 508.62 | 9,467.85 |
| | 8 | 9,467.85 | 94.68 | 608.39 | 513.71 | 8,954.14 |
| | 9 | 8,954.14 | 89.54 | 608.39 | 518.84 | 8,435.30 |
| | 10 | 8,435.30 | 84.35 | 608.39 | 524.03 | 7,911.27 |
| | 11 | 7,911.27 | 79.11 | 608.39 | 529.27 | 7,381.99 |
| | 12 | 7,381.99 | 73.82 | 608.39 | 534.57 | 6,847.43 |
| 5 | 1 | 6,847.43 | 68.47 | 608.39 | 539.91 | 6,307.52 |
| | 2 | 6,307.52 | 63.08 | 608.39 | 545.31 | 5,762.21 |
| | 3 | 5,762.21 | 57.62 | 608.39 | 550.76 | 5,211.44 |
| | 4 | 5,211.44 | 52.11 | 608.39 | 556.27 | 4,655.17 |
| | 5 | 4,655.17 | 46.55 | 608.39 | 561.83 | 4,093.34 |
| | 6 | 4,093.34 | 40.93 | 608.39 | 567.45 | 3,525.88 |
| | 7 | 3,525.88 | 35.26 | 608.39 | 573.13 | 2,952.76 |
| | 8 | 2,952.76 | 29.53 | 608.39 | 578.86 | 2,373.90 |
| | 9 | 2,373.90 | 23.74 | 608.39 | 584.65 | 1,789.25 |
| | 10 | 1,789.25 | 17.89 | 608.39 | 590.49 | 1,198.76 |
| | 11 | 1,198.76 | 11.99 | 608.39 | 596.40 | 602.36 |
| | 12 | 602.36 | 6.02 | 608.39 | 602.36 | 0.00 |

# Appendix N: Scenario 2, Annuity calculation of the Microloan to Private Households

| year | repayment periods | beginning-of-period balance | period-end interest on balance | total period-end payment | amortization of loan | end-of-period balance |
|---|---|---|---|---|---|---|
| 1 | 1 | 13,045.00 | 130.45 | 290.18 | 159.73 | 12,885.27 |
| | 2 | 12,885.27 | 128.85 | 290.18 | 161.33 | 12,723.95 |
| | 3 | 12,723.95 | 127.24 | 290.18 | 162.94 | 12,561.01 |
| | 4 | 12,561.01 | 125.61 | 290.18 | 164.57 | 12,396.44 |
| | 5 | 12,396.44 | 123.96 | 290.18 | 166.21 | 12,230.22 |
| | 6 | 12,230.22 | 122.30 | 290.18 | 167.88 | 12,062.35 |
| | 7 | 12,062.35 | 120.62 | 290.18 | 169.56 | 11,892.79 |
| | 8 | 11,892.79 | 118.93 | 290.18 | 171.25 | 11,721.54 |
| | 9 | 11,721.54 | 117.22 | 290.18 | 172.96 | 11,548.58 |
| | 10 | 11,548.58 | 115.49 | 290.18 | 174.69 | 11,373.88 |
| | 11 | 11,373.88 | 113.74 | 290.18 | 176.44 | 11,197.44 |
| | 12 | 11,197.44 | 111.97 | 290.18 | 178.20 | 11,019.24 |
| 2 | 1 | 11,019.24 | 110.19 | 290.18 | 179.99 | 10,839.25 |
| | 2 | 10,839.25 | 108.39 | 290.18 | 181.79 | 10,657.47 |
| | 3 | 10,657.47 | 106.57 | 290.18 | 183.60 | 10,473.86 |
| | 4 | 10,473.86 | 104.74 | 290.18 | 185.44 | 10,288.42 |
| | 5 | 10,288.42 | 102.88 | 290.18 | 187.29 | 10,101.13 |
| | 6 | 10,101.13 | 101.01 | 290.18 | 189.17 | 9,911.96 |
| | 7 | 9,911.96 | 99.12 | 290.18 | 191.06 | 9,720.90 |
| | 8 | 9,720.90 | 97.21 | 290.18 | 192.97 | 9,527.93 |
| | 9 | 9,527.93 | 95.28 | 290.18 | 194.90 | 9,333.03 |
| | 10 | 9,333.03 | 93.33 | 290.18 | 196.85 | 9,136.18 |
| | 11 | 9,136.18 | 91.36 | 290.18 | 198.82 | 8,937.37 |
| | 12 | 8,937.37 | 89.37 | 290.18 | 200.81 | 8,736.56 |
| 3 | 1 | 8,736.56 | 87.37 | 290.18 | 202.81 | 8,533.75 |
| | 2 | 8,533.75 | 85.34 | 290.18 | 204.84 | 8,328.91 |
| | 3 | 8,328.91 | 83.29 | 290.18 | 206.89 | 8,122.02 |
| | 4 | 8,122.02 | 81.22 | 290.18 | 208.96 | 7,913.06 |
| | 5 | 7,913.06 | 79.13 | 290.18 | 211.05 | 7,702.01 |
| | 6 | 7,702.01 | 77.02 | 290.18 | 213.16 | 7,488.85 |
| | 7 | 7,488.85 | 74.89 | 290.18 | 215.29 | 7,273.56 |
| | 8 | 7,273.56 | 72.74 | 290.18 | 217.44 | 7,056.12 |
| | 9 | 7,056.12 | 70.56 | 290.18 | 219.62 | 6,836.50 |
| | 10 | 6,836.50 | 68.36 | 290.18 | 221.81 | 6,614.69 |
| | 11 | 6,614.69 | 66.15 | 290.18 | 224.03 | 6,390.65 |
| | 12 | 6,390.65 | 63.91 | 290.18 | 226.27 | 6,164.38 |
| 4 | 1 | 6,164.38 | 61.64 | 290.18 | 228.54 | 5,935.85 |
| | 2 | 5,935.85 | 59.36 | 290.18 | 230.82 | 5,705.03 |
| | 3 | 5,705.03 | 57.05 | 290.18 | 233.13 | 5,471.90 |
| | 4 | 5,471.90 | 54.72 | 290.18 | 235.46 | 5,236.44 |
| | 5 | 5,236.44 | 52.36 | 290.18 | 237.81 | 4,998.62 |
| | 6 | 4,998.62 | 49.99 | 290.18 | 240.19 | 4,758.43 |
| | 7 | 4,758.43 | 47.58 | 290.18 | 242.59 | 4,515.84 |
| | 8 | 4,515.84 | 45.16 | 290.18 | 245.02 | 4,270.82 |
| | 9 | 4,270.82 | 42.71 | 290.18 | 247.47 | 4,023.34 |
| | 10 | 4,023.34 | 40.23 | 290.18 | 249.95 | 3,773.40 |
| | 11 | 3,773.40 | 37.73 | 290.18 | 252.44 | 3,520.95 |
| | 12 | 3,520.95 | 35.21 | 290.18 | 254.97 | 3,265.99 |
| 5 | 1 | 3,265.99 | 32.66 | 290.18 | 257.52 | 3,008.47 |
| | 2 | 3,008.47 | 30.08 | 290.18 | 260.09 | 2,748.37 |
| | 3 | 2,748.37 | 27.48 | 290.18 | 262.70 | 2,485.68 |
| | 4 | 2,485.68 | 24.86 | 290.18 | 265.32 | 2,220.35 |
| | 5 | 2,220.35 | 22.20 | 290.18 | 267.98 | 1,952.38 |
| | 6 | 1,952.38 | 19.52 | 290.18 | 270.66 | 1,681.72 |
| | 7 | 1,681.72 | 16.82 | 290.18 | 273.36 | 1,408.36 |
| | 8 | 1,408.36 | 14.08 | 290.18 | 276.10 | 1,132.27 |
| | 9 | 1,132.27 | 11.32 | 290.18 | 278.86 | 853.41 |
| | 10 | 853.41 | 8.53 | 290.18 | 281.64 | 571.77 |
| | 11 | 571.77 | 5.72 | 290.18 | 284.46 | 287.31 |
| | 12 | 287.31 | 2.87 | 290.18 | 287.31 | 0.00 |

# Appendix O: Feasibility for Farmers – 15 year development analysis

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monetary Benefit of biogas for lighting | 1,967.00 | 2,103.31 | 2,249.07 | 2,404.93 | 2,571.60 | 2,749.81 | 2,940.37 | 3,144.14 | 3,362.02 | 3,595.01 | 3,844.15 | 4,110.55 | 4,395.41 | 4,700.01 | 5,025.72 |
| Monetary benefit of saved time and additional income generation | 1,545.09 | 1,652.16 | 1,766.66 | 1,889.09 | 2,020.00 | 2,159.99 | 2,309.68 | 2,469.74 | 2,640.89 | 2,823.90 | 3,019.60 | 3,228.86 | 3,452.62 | 3,691.88 | 3,947.73 |
| Monetary benefit from fertilizer substitution | 4,000.00 | 4,277.20 | 4,573.61 | 4,890.56 | 5,229.48 | 5,591.88 | 5,979.40 | 6,393.77 | 6,836.86 | 7,310.65 | 7,817.28 | 8,359.02 | 8,938.30 | 9,557.72 | 10,220.07 |
| **Total monetary benefit** | **7,512.09** | **8,032.68** | **8,589.34** | **9,184.58** | **9,821.08** | **10,501.68** | **11,229.44** | **12,007.64** | **12,839.77** | **13,729.57** | **14,681.03** | **15,698.42** | **16,786.32** | **17,949.62** | **19,193.52** |
| Expenses for loan w/o subsidies | 8,501.28 | 8,501.28 | 8,501.28 | 8,501.28 | 8,501.28 | | | | | | | | | | |
| Expenses for loan with subsidies | 4,054.81 | 4,054.81 | 4,054.81 | 4,054.81 | 4,054.81 | | | | | | | | | | |
| Expenses for the operation (water) | 309.35 | 330.79 | 353.71 | 378.22 | 404.43 | 432.46 | 462.43 | 494.48 | 528.75 | 565.39 | 604.57 | 646.47 | 691.27 | 739.17 | 790.39 |
| Expenses for disuse of farming land | 1,500.00 | 1,603.95 | 1,715.10 | 1,833.96 | 1,961.05 | 2,096.95 | 2,242.27 | 2,397.66 | 2,563.82 | 2,741.49 | 2,931.48 | 3,134.63 | 3,351.86 | 3,584.15 | 3,832.53 |
| Expenses for maintenance | 48.91 | 52.30 | 55.92 | 59.80 | 63.94 | 68.37 | 73.11 | 78.18 | 83.60 | 89.39 | 95.59 | 102.21 | 109.29 | 116.87 | 124.97 |
| **Total expenses w/o subsidies** | **10,359.54** | **10,488.32** | **10,626.02** | **10,773.26** | **10,930.71** | **2,597.79** | **2,777.82** | **2,970.32** | **3,176.16** | **3,396.27** | **3,631.63** | **3,883.31** | **4,152.42** | **4,440.18** | **4,747.89** |
| **Total expenses with subsidies** | **5,913.07** | **6,041.85** | **6,179.55** | **6,326.80** | **6,484.25** | **2,597.79** | **2,777.82** | **2,970.32** | **3,176.16** | **3,396.27** | **3,631.63** | **3,883.31** | **4,152.42** | **4,440.18** | **4,747.89** |
| **Overall w/o subsidies** | **-2,847.45** | **-2,455.64** | **-2,036.67** | **-1,588.68** | **-1,109.63** | **7,903.88** | **8,451.62** | **9,037.32** | **9,663.61** | **10,333.30** | **11,049.39** | **11,815.12** | **12,633.90** | **13,509.43** | **14,445.64** |
| **Overall with subsidies** | **1,599.02** | **1,990.83** | **2,409.79** | **2,857.79** | **3,336.83** | **7,903.88** | **8,451.62** | **9,037.32** | **9,663.61** | **10,333.30** | **11,049.39** | **11,815.12** | **12,633.90** | **13,509.43** | **14,445.64** |