TECHNISCHE UNICERSITÄT MÜNCHEN
Lehrstuhl für Wirtschaftslehre des Landbaues

Economic and Ecological Aspects of Biogas Scene in China

Pingping Nie

Vollständiger Abdruck der von der Fakultät Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt der Technischen Universität München zur Erlangung des akademischen Grades eines

Doktors des Agrarwissenschaften (Dr. agr.)

genehmigten Dissertation.

Vorsitzender: Univ.-Prof. Dr. M. Faulstich

Prüfer der Dissertation:

1. Univ.-Prof. Dr. Dr. h.c. A. Heißenhuber
2. Univ.-Prof. Dr. H. Bernhardt
3. Univ.-Prof. Dr. Z. Li (University of Science & Technology, Beijing)

Die Dissertation wurde am 08.07.2010 bei der Technischen Universität München eingereicht und durch die Fakultät Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt am 13.10.2010 angenommen.

Thanksgiving

This dissertation would not have been possible without the contribution of several people. First of all, I can hardly express the gratitude I owe to my parents. Thanks their encouragement and being by my side always.

I categorically express my heart felt gratitude to my Professor, Prof. Dr.Dr.h.c. Alois Heissenhuber for his dedication and vital corrections and encouragement to work on this very interesting subject. Thanks the predestined relationship that I can be your student. Thanks for holding my hand to give me a new life experience and for the first bicycle you made me. I also express my appreciation for your patience, encouragement, belief and for giving me lots of opportunities to take part in conferences.

I also thank the German Academic Exchange Service (DAAD), for granting me financial support during my doctoral research.

Furthermore, I would like to thank my supervisor Dr. Hubert Pahl for the open door and for giving me knowledge. It is my pleasure to have worked with you during the course of writing this dissertation.

Thanks a lot Prof. Dr. Zifu Li for being my examiner and for the meetings of Beijing Science and Technology University. Thanks indeed for your help and warm care for my work. You are my model. To Prof. Dr. Heinz Bernhardt, I would express special thanks for being my examiner as well.

I express my gratitude to three warm-hearted colleagues Mr. Stefan Rauh, Dr. Martin Kapfer and Dr. Petra Huck, who always assisted matters concerning technical work and detailed explanation. Special thanks to Ms. Elizabeth Anita Hamzi-Schmidt for the predestined relationship! Thanks for assisting with the editing of this dissertation. I enjoyed every moment spent with you doing this work and wish I could always meet you in my life. I sincerely thank Mr. Samuel Kwesi Osei who also spent his limited weekends editing this dissertation. Finally, I say thank you to every colleagues in the Institute. It is my pleasure to have met with you and to have worked with you all.

Index of content

Index of Figures **6**

Index of Tables **8**

Index of Maps **10**

List of abbreviations **11**

1 Introduction **12**

1.1 Problem Statement 12

1.2 The goals of the study 14

1.3 Structure of the study 15

2 Literature review and background **17**

2.1 General development 17

2.1.1 Biogas development and technology in China's rural areas 17

2.1.2 Biogas utilization in Germany 21

2.2 Kyoto Protocol and Clean Development Mechanism 24

2.2.1 General information about Kyoto Protocol and Clean development mechanism 24

2.2.2 CDM project activities in China 27

3 Methodologies **30**

3.1 Economic methodologies 30

3.1.1 Costs-revenue analyses 30

3.1.2 Sensitivity analysis 32

3.1.3 Break-even analysis 34

3.1.4 The “Worst”, “normal” and “best” cases analysis 35

3.1.5 Cash flow and liquidity 36

3.1.6 Monte-Carlo-Simulation 37

3.2 Ecological methodologies 41

3.2.1 Consolidated baseline methodology for GHG emission reductions from manure management systems 41

3.2.2 Methane recovery in agricultural activities at household/small farm level 48

3.2.3 Costs of CHG emission reduction 50

4 Economic and ecological aspects of biogas projects 52
4.1 Economic and ecological aspects of household biogas project 52
4.1.1 Project background 52
4.1.2 Economic analyses 56
4.1.2.1 Cost-revenue analyses 56
4.1.2.2 Sensitivity analysis 66
4.1.2.3 The “Worst”, “normal” and “best” cases 68
4.1.2.4 Monte- Carlo- simulation risk analysis 70
4.1.3 Ecological analyses 73
4.1.3.1 Carbon dioxide emission analysis 74
4.1.3.2 Costs of carbon dioxide emission reduction 77
4.1.3.3 Cash flow and liquidity (with CERs) 80
4.2 Economic and ecological analyses of medium scale dairy farm biogas electricity generation project 81
4.2.1 Project background 81
4.2.2 Economic analyses 88
4.2.2.1 Cost-revenue analysis 88
4.2.2.2 Sensitivity analysis 92
4.2.2.3 Break-even analysis 95
4.2.2.4 The “Worst“, “normal” and “Best” cases analysis 96
4.2.2.5 Monte-Carlo-Simulation risk analysis 99
4.2.3 Ecological analyses 103
4.2.3.1 Carbon dioxide emission analyses 103
4.2.3.2 Costs of carbon dioxide emissions 106
4.2.3.3 Cash flow and liquidity (with CERs) 110
4.3 Economic and ecological aspects of a large scale chicken farm biogas electricity generation project 112
4.3.1 Project background 112
4.3.2 Economic analyses 115
4.3.2.1 Cost-revenue analysis 116
4.3.2.2 Sensitivity analysis 119
4.3.2.3 Break-even analysis 120
4.3.2.4 The“Worst”, “normal” and “best” cases analyses 122
4.3.2.5 Cash flow and liquidity 124
4.3.2.6 Monte-Carlo-Simulation 126
4.3.3 Ecological analyses 132
4.3.3.1 Carbon dioxide emissions analysis 133
4.3.3.2 Costs of carbon dioxide emission reduction 135
4.3.3.3 Cash flow and liquidity (with CERs) 140

5 Discussion and conclusion ... 143

5.1 Economic and ecological aspects for selected three biogas projects ... 143

5.1.1 Project background ... 143

5.1.2 Government bonus ... 148

5.1.3 Impact of CDM ... 151

5.2 Economic and ecological aspects concerning German biogas projects ... 156

5.2.1 The economical aspects of biogas projects ... 156

5.2.2 The methodology concerning the ecological aspects of carbon dioxide emissions ... 159

6 Summary ... 164

7 Literature ... 168

8 Annex ... 177

Index of Figures

Figure 1: “One household one tank” technology ... 18
Figure 2: The medium scale biogas project for electricity and heat generation for local utilization ... 19
Figure 3: The large scale biogas project for electricity and heat generation for feeding into the national grid ... 20
Figure 4: Number of biogas plants and installed electricity capacitity ... 23
Figure 5: Diagram of CDM in Kyoto Protocol ... 24
Figure 6: CDM Project Cycle ... 25
Figure 7: A flow diagram showing the process of biogas generation and transmission ... 30
Figure 8: Sensitivity analysis ... 33
Figure 9: Sensitivity analsysis ... 34
Figure 10: Break-even Analysis ... 35
Figure 11: The „worst“, the „normal“and the „best“cases ... 36
Figure 12: An example of frequency and distribution function ... 39
Figure 13 Bandwidth of the profit in the simulation of individual variables and change in the distribution function by optimizing operation ... 40
Figure 14: Project activity boundary ... 43
Figure 15: Thermal energy production costs depending on parameters change ... 67
Figure 16: The “Worst”, “Normal” and “Best” cases in project activity ... 69
Figure 17: Density function from 15 m^3 biogas digester ... 70
Figure 18: Distribution function from 15 m^3 biogas digester ... 71
Figure 19: Imputed profit band for 15 m^3biogas digester ... 71
Figure 20: Effect of essential parameters in imputed profit for biogas digester with 15 m^3 ... 72
Figure 21: Baseline emission, project emission and emission reduction for each of digester size of biogas thermal energy production ... 76
Figure 22: GHG emission reduction costs of thermal energy production for 10 m^3 digester.. 79
Figure 23: Cash flow and liquidity of project activity with possible carbon income ... 80
Figure 24: Biogas electricity generation operating system ... 83
Figure 25: Biogas electricity generation energy balance ... 87
Figure 26: Costs, revenue and profit/lost situation for Scenario I and II ... 91
Figure 27: Sensitivity analysis and return rate of investment for scenarios I and II ... 93
Figure 28: Sensitivity analysis for scenarios I and II ... 94
Figure 29: Break-even analysis for Scenario II ... 95
Figure 30: “Worst”, “normal” and “best” cases analysis for Scenario I ... 97
Figure 31: “Worst”, “normal” and “best” cases analysis for Scenario II ... 98
Figure 32: Density function of biogas project with Scenario II ... 99
Figure 33: Distribution function of biogas project with Scenario II ... 100
Figure 34: Distribution function from effect of some essential factors changing ... 101
Figure 35: Imputed profit band ... 102
Figure 36: Baseline emissions, project emissions, leakeage emissions and emission reduction for electricity generation concerning Scenario I and II ... 105
Figure 37: CO_2 emission reduction in Scenario I ... 109
Figure 38: CO_2 emission reduction in Scenario II ... 110
Figure 39 Financial liquidity with the equivalent carbon price of 10 $/t$CO_{2e}$ and minimum CDM preparation costs for Scenario II ... 111
Figure 40: Annual costs, revenue and profit for Scenario I and II ... 118
Figure 41: Sensitivity analysis of return on equity for Scenario I and II ... 119

Figure 42: Break-even analysis for Scenario I 121
Figure 43: Break-even analysis for Scenario II 121
Figure 44: The “Worst”, “normal” and “best” cases for Scenario I 123
Figure 45: The “Worst”, “normal” and “best” cases for Scenario II 123
Figure 46: Cash flow and liquidity analysis for Scenario I 125
Figure 47: Cash flow and liquidity analysis for Scenario II 126
Figure 48: Density function of Scenario I 127
Figure 49: Density function of Scenario II 128
Figure 50: Distribution function of biogas project with Scenario I and II 128
Figure 51: Distribution function from effect of some essential factors changing for Scenario I 129
Figure 52: Distribution function from effect of some essential factors changing for Scenario II 130
Figure 53: Imputed profit band for biogas digester with Jenbache CHPP 131
Figure 54: Imputed profit band for biogas digester with Shengdong CHPP 131
Figure 55: Baseline emissions, project emissions, leakeage emissions and emission reduction for electricity generation related to Scenario I and II 135
Figure 56: Costs of CO_{2e} of electricity production and CO_{2e} for Scenario I 139
Figure 57: Costs of CO_{2e} of electricity production and CO_{2e} for Scenrio II 140
Figure 58: Financial liquidity with carbon price of 10 \$/tCO_{2e} equivalent and proposed maximum CDM preparation costs for Scenario I 141
Figure 59: Financial liquidity with carbon price of 10 \$/tCO_{2e} equivalent and proposed maximum CDM preparation costs for Scenario II 141
Figure 60: Costs, revenue and profit for case I and II relating to the second project 146
Figure 61: Impact of CDM on medium scale biogas electricity generation project with a bilateral or multilateral approach 153
Figure 62: Impact of CDM on medium scale biogas electricity generation project with unilateral approach 153
Figure 63: Comparison of costs and renuve for Chinese and German projects 158
Figure 64: Procedure of GHG emissions of rural German biogas production 159
Figure 65: GHG emissions and emission reduction for selected Chinese projects and a German project 162

Index of Tables

Table 1: Compensation for biomass under the implementation of RESA in 2004 21
Table 2: Comparison of Compensation for biomass bonus between 2004 and 2009 within the framework of RESA 22
Table 3: Mainly financing implementation CDM forms 26
Table 4: CDM project distribution and emission reduction by projects 27
Table 5: Calculation model in the three projects.. 31
Table 6: Cash flow and liquidity for a biogas project 37
Table 7: Calculation of NPV and IRR 43
Table 8: Project information 55
Table 9: Cost situation of household biogas digester.. 56
Table 10: The annual biogas digesters project imputed costs from farmers investment share 58
Table 11: Default number for biogas production from swine waste calculation 60
Table 12: Biogas production in eight cities and counties in Enshi administrative region 60
Table 13: Required coal consumption... 61
Table 14: Costs for total energy production from biogas and from coal consumption............ 62
Table 15: Annual biogas production, thermal value and coal saving in household digester size of 8m^3, 10m^3, 12m^3 and 15m^3 63
Table 16: The annual biogas digesters project imputed costs from project total investment .. 64
Table 17: Costs for total energy production from project biogas production and from coal consumption 65
Table 18: Baseline emissions 74
Table 19: Project emissions.. 75
Table 20: Household emission reduction 75
Table 21: Total project GHG emissions and emission reduction.. 76
Table 23: CO$_2$ emission reduction costs for project activity based on traditional method of waste disposal 77
Table 22: CO$_2$ emission reduction costs between thermal energy productions from project activity of biogas production and coal consumption....................................... 78
Table 24: Daily dairy cattle waste production 82
Table 25: Total costs calculation for biogas electricity generation project and organic fertilizer project. (Scenario I).. 84
Table 26: Investment costs changing for the project construction (Scenario I and II) 85
Table 27: Investment costs changing concerning project equipment (Scenario I and II)........ 86
Table 28: Total costs calculation for biogas electricity generation project (Scenario II) 86
Table 29: Annual imputed costs evaluation for Scenario I 88
Table 30: Annual electricity and heat production, revenue calculation for Scenario I............ 89
Table 31: Annual imputed costs evaluation for Scenario II... 90
Table 32: Annual electricity and heat production, revenue calculation for Scenario II........... 91
Table 33: Baseline emissions for Scenario I and II, tCO$_{2e}$/a.. 104
Table 34: Project emissions for Scneario I and II, tCO$_{2e}$/a 104
Table 35: Emission leakage, tCO$_{2e}$/a 104
Table 36: Difference of costs of electricity between biogas production and coal consumption for Scenario I... 106
Table 37: CO$_2$ emission reduction between biogas production and coal consumption for Scenario I... 107
Table 38: CO$_2$ emission reduction costs for Scenario I 107

Table 39: Difference of costs of electricity between biogas production and coal consumption for Scenario II 108
Table 40: CO_2 emission reduction between biogas production and coal consumption for Scenario II 108
Table 41: CO_2 emission reduction costs for Scenario II 109
Table 42: Description of the study model farm 114
Table 43: CHPP parameters from Jenbacher and Shengdong 115
Table 44: Annual costs calculation with the Jenbacher’s and Shengdong’s CHPPs 117
Table 45: Annual electricity and heat production, revenue calculation for Scenario I and II 118
Table 46: Baseline emissions 133
Table 47: Project emission 134
Table 48: Emission reduction 134
Table 49: Difference in costs of electricity between biogas production and coal consumption for Scenario I 136
Table 50: CO_2 emission reduction between biogas production and coal consumption for Scenario I 136
Table 51: CO_2 emission reduction costs for Scenario I 137
Table 52: Difference in costs of electricity between biogas production and coal consumption for Scenario II 137
Table 53: CO_2 emission reduction between biogas production and coal consumption for Scenario II 138
Table 54: CO_2 emission reduction costs for Scenario II 138
Table 55: Costs difference between two cases with different investment sources 145
Table 56: Costs, revenue and profit related to the second project 145
Table 57: Costs, revenue and profit/loss situation for medium scale biogas project 149
Table 58: Impact of CDM on annual imputed costs, revenue and profit/loss concerning the second project 152
Table 59: Review of costs and revenue for medium and large scale biogas plants 156
Table 60: Project data 157
Table 61: Annual costs and revenue 157
Table 62: Difference between the methodologies of UNFCCC and that of German institutes 160

Index of Maps

Map 1: The annual income in Hubei province 53
Map 2: Biogas project with “one household one tank” system.. 54
Map 3: Project Area 54
Map 4: Geographic location of Deqingyuan farm 112
Map 5: Deqingyuan recycling “eco- farm” model 113

List of abbreviations

approx.	Approximately
AWMs:	Animal waste management system
BEP:	Break-even point
CDM:	Clean Development Mechanism
CER:	Certified emission reduction
CHPP:	Combined heat and power plant
DNA:	Designated National Authority
DOE:	Designated Operating Entity
EB:	Executive Board
etc:	et cetera
EU:	European Union
FM:	Fresh matter
GHG:	Greenhouse gas
i.e.:	id est
IRR:	Internal rate of return
kg:	Kilogram
KW_{el}:	Electric kilowatt
MW_{el}:	Electric Megawatt
kWh_{el}:	Electric kilowatt-hour
kWh_{th}:	Thermal kilowatt-hour
kWh:	Kilowatt-hour
m^3 :	Cubit meter
MJ:	Megajoules
MOA:	Ministry of Agriculture
NPV:	Net Present Value
oTS:	Organic dry matter
PIN:	Project idea Note
PP:	Project proponents
REL:	Renewable Energy Law
RESA:	Act of Renewable Energy Sources
t:	ton
TM:	Dry matter
UNEF:	United Nations Environment Programme
$:	US. Dollar
RMB:	Chinese Yuan

1 Introduction

The concept of biogas development in China has increased tremendously in recent years. Biogas development in China is different compared to that found in Europe in terms of size and investment costs. For example, the size of fermentation plant depends on the scale of the biogas project ranging from 8 m^3 to 20,000 m^3, considering the investment costs of 3,085 RMB (equal to 400 \$) to 48 million RMB (equal to 6 million \$) (MOA, 2006b). Some projects attract governmental support with the "gift interest"[1] and enjoy the coorporation with the top foreign banks (MOA, 2008). Similar biogas projects must seek financial support by themselves. It is a pity that some biogas projects are operated without having adequate planning mechanisms in place. Moreover, with the emergence of world carbon trade market systems in recent years, some biogas projects should be able to accrue profits. Nevertheless, there are some projects which have failed lacking compensation capability, even at the initial stage of applying for the carbon trade project (Kyoto University, 2006). Furthermore, biogas projects result in carbon dioxide emission reduction. In that context, although Chinese biogas projects have more potential for reducing carbon dioxide emissions in the world, in fact, they have little influence on the carbon trade market (Zhang et al., 2010). However, there is no doubt that biogas research has ushered an unpresendented development. With the introduction of rural biogas project, the energy needs of farmers in the long-term will be curtailed, this will not only ensure the improvement in the livelihood of farmers, but also secure sustainable agricultural development, an increase in the income of farmers and maintain the ecological balance (Han et al., 2008). In fact, the achievement of this standard in both economic and ecological terms presents a huge challenge for the Chinese government and the project owners (China new energy information, 2007).

1.1 Problem Statement

Although the biogas boom in China has reached significant proportions, there are still some problems which need to be tackled concerning biogas development (Li, 2006). The problems are presented as follows:

The first problem has to do with the difficulty of the implementation of the biogas project. Household biogas projects have been developed since 1990s. Thanks to the continuing

---

[1] Gift interest in this context referes to low interest rate on the funds that need to be paid back by project owners

research and experience, this technology has already matured. But in some of the Chinese provinces the household biogas project is difficult to implement (Liua et al., 2008). The reason being there is generally a lack of technical knowledge about biogas utilization (Chen, 1997). A good example in this context is the case of the antibiotic medication fed to the livestock. Due to the special character of the anaerobic process during the biogas production, the animal waste containing antibiotec could obstruct biogas production (Bhattacharya et al, 2002). Secondly, the traditional idea of using fuel wood as a source of energy is a contributing factor causing the delay in the implementation of the biogas project. It is interesting to note that some of fossil energy is easy to obtain and could also be used directly with their higher energy content in rural areas (Yua et al, 2008). The biogas electricity generation project could also face great challenge in project implementation. Regarding waste disposal in livestock farms, the farmers could rather use the animal waste as fertilizer on their fields (Wang, 2005). The benefits from such fertilizer application outweigh the costs of the biogas project installation, finances and knowledge transfer.

The second problem is the lack of financial support. Under the Renewable Energy Law (REL) established in the year 2006, government gave funding to the biogas project with maximum sum of 200,000 RMB as financial support towards investment costs (MOA, 2008). This means that the biogas project can obtain the financial support at the beginning of project plan, In this context, the sum would not exceed 1/2 of total investment costs. Unfortunately, not every biogas project would obtain this kind of financial support, although some projects qualify for such funding (Li et al, 2005). Moreover, the project owners are encouraged to seek financial support from foreign banks. In that context, the project owner neither has information about the application procedure to request funding, nor does the project owner obtain financial support from the Chinese government (Vanburen, 1980). In view of that, the project could not be operational.

The third problem is insufficient project planning. Since the government support has been implemented, more biogas projects have sprung up (Urmee et al., 2009). Some of the projects are not being researched into by professional institutes. Earlier experience with other projects is resorted to, so as to rectify identified mistakes before project implementation. In this case, the project is duplicated from those funded projects already existing. Due to the difference in local customs and practices and physical conditions in Chinese provinces, the same type of project may present different results when implemented in other areas (Li et al., 2005). Moreover, for the biogas electricity generation project, the project owner invests in expansive and effective power generation or other equipment blindly, which does not necessarily fit in with the concept of the project (China newenergy information, 2007). It results in the squandering of financial resources. The problem of insufficient planning for the carbon project may also result in a loss of money (UNFCCC CDM Executive Board, 2002). Due to the long-term application process for the carbon project, the projects would have made use of a large amount of money previously. If the implementation of project results were to be unsuccessful, the project could risk losing out on the opportunity of becoming a carbon project. In that context, there will be a need re-application (Institute for Global Environmental Strategies, 2006).

The fourth problem is considered to be the minor influence on the carbon market. It is interesting to indicate that the number of biogas plants already existing in China to date gives this nation the first position globally but in reality, the buyers from the developed nations determine the price (Kyoto University, 2006). Moreover, due to the smaller amount of carbon dioxide emission reduction compared with other types of renewable energy projects (water energy project, wind energy project, coal conversation project, etc.), the biogas project owner finds it hard to get some kind of support when applying for a carbon project. In this case, some biogas project owners earn more profit and so blindly grab any foreign support available, especially from small to medium-sized foreign companies (Zhang et al., 2008). It is clear that the Chinese project owner may be relieved of the financial burden and thus is less at risk of applying for a carbon project. However, it may result in the reduction of the carbon price and damage the carbon trade market’s future. As the country with the largest carbon trade potential, the result would also be meaningful for China’s carbon trade (Liu et al., 2008).

1.2 The goals of the study

The local government advocates and encourages environment protection and the efficient utilization of animal waste as biomass for energy production. This is also a key method and a global aim (China Economic Review, 2001). There is abundant animal waste produced annually in Chinese rural households and livestock farms. According to the Chinese environmental law, it is forbidden to dump animal waste in rivers as this may contaminate the rivers or fields. Converting the waste into a valuable resource for energy utilization must, however, be encouraged (MOA, 2008). Due to the rapid development of animal waste for biogas production, from the year 2000 to 2006, local government planned three projects (MOA, 2006b); a household biogas project for domestic use by the rural population in Hubei Enshi province, a biogas electricity project for local utilization in dairy farm in Zhejinag province and a biogas electricity generation project for feeding into the national grid in Beijing Deqingyuan Farm.

With the continuous amendment of the REL, biogas could not only be substituted for primary household energy utilization, but also produce electricity or heat for use for livestock (Shi, 2000). Many biogas plants could be utilized for combining the generation of both power and heat energy. Furthermore, the number of biogas plants increased rapidly with special reference to the development of large scale biogas electricity generation plants with an appropriate substrate demand (Hubei Statistics Bureau, 2006). With the rapid increase in biogas plants, the question is, "Can the biogas projects help in achieving economic and ecological benefits so as to ensure the sustainable development of rural areas?" The following objectives will provide answers to the research question indicated above.

Objectives of the study

1) To make an economic analysis with the help of some general methods for three selected projects.

2) To assess the ecological impact of the projects using the Clean Development Mechanism (CDM) method for carbon dioxide estimation.

1.3 Structure of the study

The literature review and background to the biogas scene is presented in the next chapter. First, the main Chinese biogas project development and technologies are described. Secondly, the German biogas development and the effect of the amendment of the Act of Renewable Energy Sources (RESA) in Germany are presented. (Chapter 2).

Some important economic and environmental methodologies are indicated in the third chapter. The economic methodologies include the cost-revenue analysis, sensitivity analysis, break-even analysis, the "worst", the "normal" and the "best" cases analysis, cash flow and liquidity analysis as well as the Monte-Carlo Simulation. The CDM is used in terms of the environmental methodology (Chapter 3).

The mainpart of this study consists of economic and environmental analyses for three biogas projects. The first project is a household biogas project for thermal energy utilization. The second and the third projects are biogas projects for electricity production. The biogas from the second project is meant for local utilization. The third, for sale to feed into the national grid. The analysis can be separated into two main parts:

- ✓ Economic analysis, useing some popular methodologies to evaluate total costs, revenue and project profit. Following that the sensitivity analysis, financial liquidity and monte carlo simulation for project risk are evaluated.
- ✓ Ecological analysis is done based on the method for the CDM (Chapter 4).

In conclusion, the result of the economic and ecological analyses for the three selected biogas projects will be presented and discussed. Moreover, there are also some points which need to be discussed concerning project background, a bonus sheme from government and the impact of CDM. Moreover, the results of the analyses of the selected biogas projects will be compared with that of those in Germany (Chapter 5). Futhermore, the summary for this study is presented in Chapter 6.

2 Literature review and background

The two parts relating to the general development and Kyoto Protocol and CDM will be shown in this chapter. The general development for both the China and Germany will be considered first. Second, the general information and project activities in China will be presented later.

2.1 General development

Biogas has been developed over many decades both in China and in Germany. In recent years, there are also more and more technical and institutional cooperations between the two countries (Institute for Global Environmental Strategies, 2006). Moreover, both countries have gained specialised “know-how” regarding biogas technology and utilization. Thus, this part will present the development of biogas in China and biogas utilization in Germany.

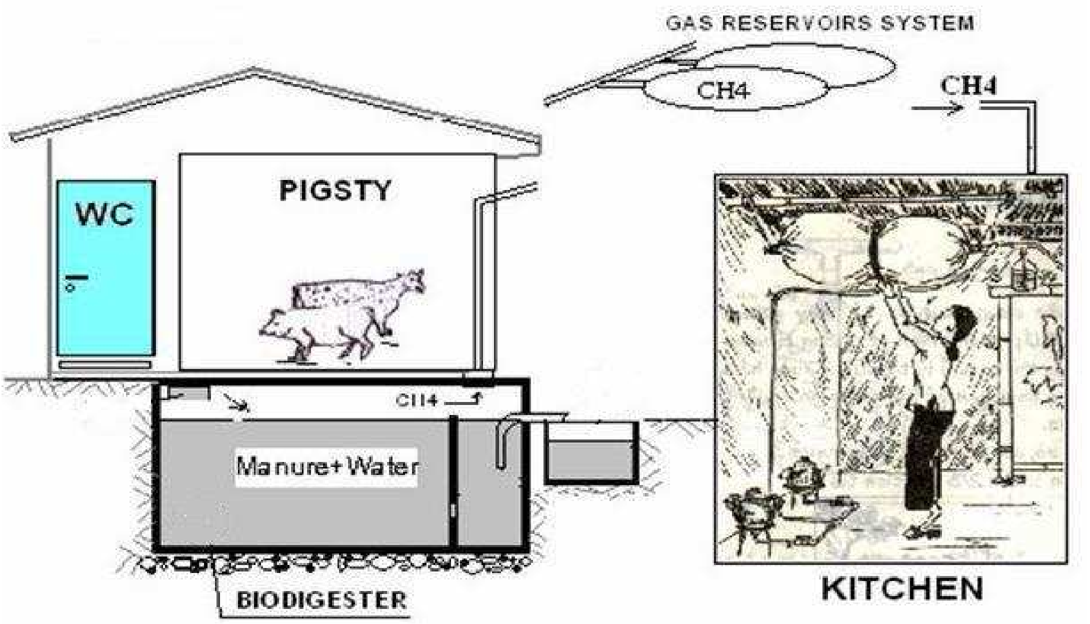
2.1.1 Biogas development and technology in China's rural areas

Biogas development has been developed since 90’s in China. There are many biogas projects which operate in rural area. The development of biogas scene has increased rapidly in recent years., thus the use of the technology has risen sharply (Liu et al., 2008). The following technologies are indicated in biogas development for rural areas in China:

1. “One household one tank”

This kind of technology has been extensively utilized in many Chinese rural areas. Due to the lack of economic resources, many farmers are not be able to consume fossil energy sustainablely (Chen, 1987). The large amount of waste from livestock means that the farmers can use biogas to cook, and to heat their homes/barns. In this case, the household biogas project can be considered (Yue et al., 2008). This technology utilization can not only relieve the difficulty of fossil energy acquisition for rural populations, but also serve as a substitute for fossil energy, so as to reduce carbon dioxide emissions. Normally, the animal sheds, the toilet, biogas digester and kitchen should be connected (Yu et al., 2008). Thanks to the biogas utilization, the human and animal wastes would be disposed of, therefore, reducing the risk of pests. Figure 1 depicts the “One household one tank” technology.

Figure 1: “One household one tank” technology



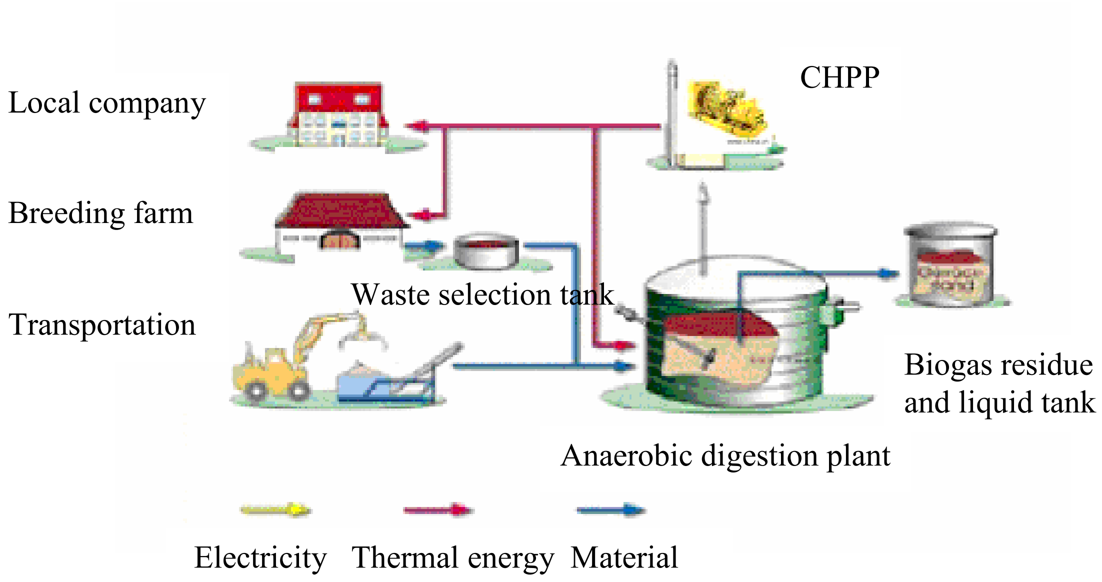
Source: MOA, 2006b

In Figure 1, the animal shed (pigsty), the toilet, biogas digester and kitchen are connected to one another. The biogas digester is built just beneath the animal shed (pigsty) and toilet. The waste from human and animal can be directly transported to the digester to generate biogas. Biogas can be piped to cooker and heating (Zhao, 1985). Normally, the household biogas project size is between 8 m^3 to 20 m^3, depending on the population in the household.

2. The medium scale biogas project with electricity generation for local utilization

This kind of project is utilized for medium scale livestock farms. Due to the large quantity of daily animal waste production, the waste can be used for biogas production. Biogas can be generated for electricity and heat energy (El-Mashad, 2007). To generate energy from biogas production, highly equipment and technology must be considered. In this context, the anaerobic fermentation technology, as well as the combined heat and power plant (CHPP) technology has, in recent years, developed rapidly in China. Since a small amount of energy is produced, the generated electricity and heat is used only for local farm utilization, thereby substituting fossil energy for biogas (Rural Energy Development in China, 1994). Moreover, a larger amount of carbon dioxide emissions which can be reduced compared with the household biogas project. This may bring economic benefit to the project owners in the carbon trade market (Su et al., 2003). Thus, Figure 2 indicates the medium scale biogas project with electricity and heat generation for local utilization.

Figure 2: The medium scale biogas project for electricity and heat generation for local utilization



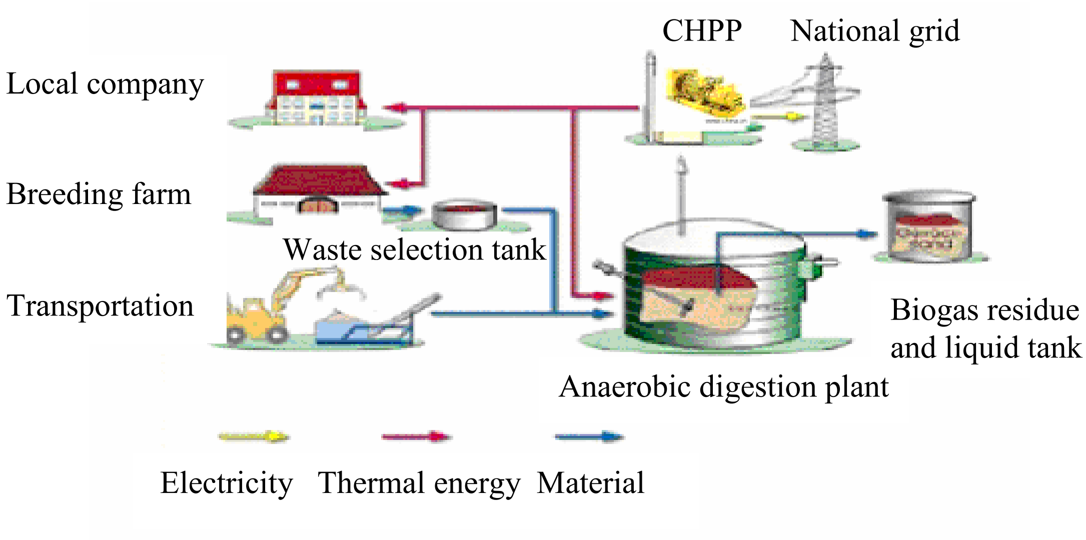
Source: BioenergyGermany, 2008

Figure 2 shows the medium scale biogas project with electricity and heat generation for local utilization. The waste from breeding farm is first selected and then transported to the project site. The next stage is the same as in the "one household one tank" technology, in which the waste is channeled into biogas production. In addition, the biogas produced can be used to generate electricity and heat energy for local company and breeding farms. Furthermore, the biogas residue and liquid can be processed for fertilizer application for arable farming.

3. The large scale biogas project with electricity generation for feeding into the national grid

China has plenty of livestock. There are also many large scale livestock farms in the country. Therefore, plenty of animal waste is discharged (Wu, 1987). Especially in the eastern part of China, the large scale farms are blessed with unique advantages for biogas production and continuing energy generation (Rural Energy Development in China, 1994). Due to the relatively large amount of energy production, the produced electricity can be sold and fed into the national grid. The project owners would obtain biomass bonus with 0.25 RMB/kWh$_{el.}$(MOA, 2008). Since plenty of animal waste can be discharged, the project owners not only protect environment, but also achieve economic benefits and receive financial rewards (Luo, 2009). The technical process is similar to the technology of the second project (a medium scale biogas project with electricity and heat generation for local utilization). Only the generated electricity can be sold for feeding into the national grid. In this case, the CHPP with greater efficiency makes for biogas electricity production more economically viable (Wang, 2002). Furthermore, the carbon benefit would make the project more beneficial.. Figure 3 illustrated this kind of technology.

Figure 3: The large scale biogas project for electricity and heat generation for feeding into the national grid



Source: BioenergyGermany, 2008

Figure 3 shows the large scale biogas project with electricity generation for feeding into the national grid. Larger amounts of animal waste could generate more electricity. In this context, it makes economic sense for the project owners to sell the generated electricity.

Since the 2006, more and more biogas projects have been operating within the framework of carbon dioxide trade. This means, the project owners can not only obtain economic benefit from project operation, but also from the carbon dioxide trade with the buyers from industrialised countries. In this context, the biogas scene would bring more economic and ecological benefits (Biogas from Excreta, 2002).

Due to the different technology implementation, China’s biogas research has been developed rapidly. Germany, as one of the first countries with biogas utilization, has obvious achievement in this field (LFL, 2006a). Thus, in the next part of this chapter, the biogas utilization in Germany will be introduced.

2.1.2 Biogas utilization in Germany

Currently, there are many kinds of cooperations for biogas projects between China and Germany. German biogas technology had been developed for several years. To data, the country has advanced technology, especially for biogas energy generation, making it one of the most energy efficient countries in the world (Besgen et al., 2007). Furthermore, the RESA has been amended twice after its initial introduction in Germany. The RESA has played an important role in German biogas development. The RESA was promulgated in February 2000 (BioenergyGermany, 2008). Thanks to RESA, the biogas project guaranteed the sale of generated electricity fed into the national grid The project owners can obtain a biomass bonus from electricity generation from 17 to 20 cents depending on the capacity category and project's life-span. In the year 2004, the RESA was amended for the very first time. One of the most essential changes is the implementation of a biomass bonus for the renewable resources, as well as a bonus of CHPP and a technology bonus (BMU, 2008). The first amendment of RESA categorised the biogas plants giving different amount of bonus. Table 1 shows the compensation for biomass under the implementation of RESA in 2004.

Table 1: Compensation for biomass under the implementation of RESA in 2004

Type of bonus	Period established ①	0-150 KW$_{el}$ (cent/kWh$_{el}$)	150-500 KW$_{el}$ (cent/kWh$_{el}$)	500 kW$_{el}$-5 MW$_{el}$ (cent/kWh/$_{el}$)	>5 MW$_{el}$ (cent/kWh$_{el}$)
Basic	Old	17-20			
	New	11.5	9.9	8.9	8.4
Renewable energy	Old	6	6	4	-
	New	6	6	4	-
Conbined heat and power plant	Old	-	-	-	-
	New	2	2	2	2
Technology	Old	-	-	-	-
	New	2	2	2	-

Source: BMU, 2008

Note:

① *The period of establishment: the old plants were setup before 31st December,.2003, and the new plants after 1st January,.2004*

In Table 1, the bonuses are categorised into four groups: basic, renewable energy, CHPP and technology. Moreover, the bonus was also implemented with reference to different periods, considering old and new projects established. Concerning the basic bonus, there is no difference between old plants and new plants. With reference to the new plants, the basic bonus would have been from 11.4 cent to 8.4 cent depending on the plant category of installed capacity ranging from 150 kWh$_{el}$ to above 5 MW$_{el}$ (BMU, 2008). Within the framework of RESA the bonus for renewable energy resources in 2004 has been very important. All biogas plants, except those which fall in the project category above 5 MW$_{el}$ would be benefit from this kind of bonus which is independent of the period established. Furthermore, the new established plant could benefit from the CHPP bonus as well as the technology bonus.

After the implementation of RESA in 2004, the installed electricity capacity increased rapidly. By the end of 2008, the RESA had been amended for the second time. In that context, the bonus obtained from animal waste was added to the RESA in 2009. Other bonuses included that of emission reduction and landscape protection (BMU, 2009). Table 2 shows the comparison between the compensation of the biomass bonus for 2004 and 2009 within the framework of RESA.

Table 2: Comparison of Compensation for biomass bonus between 2004 and 2009 within the framework of RESA

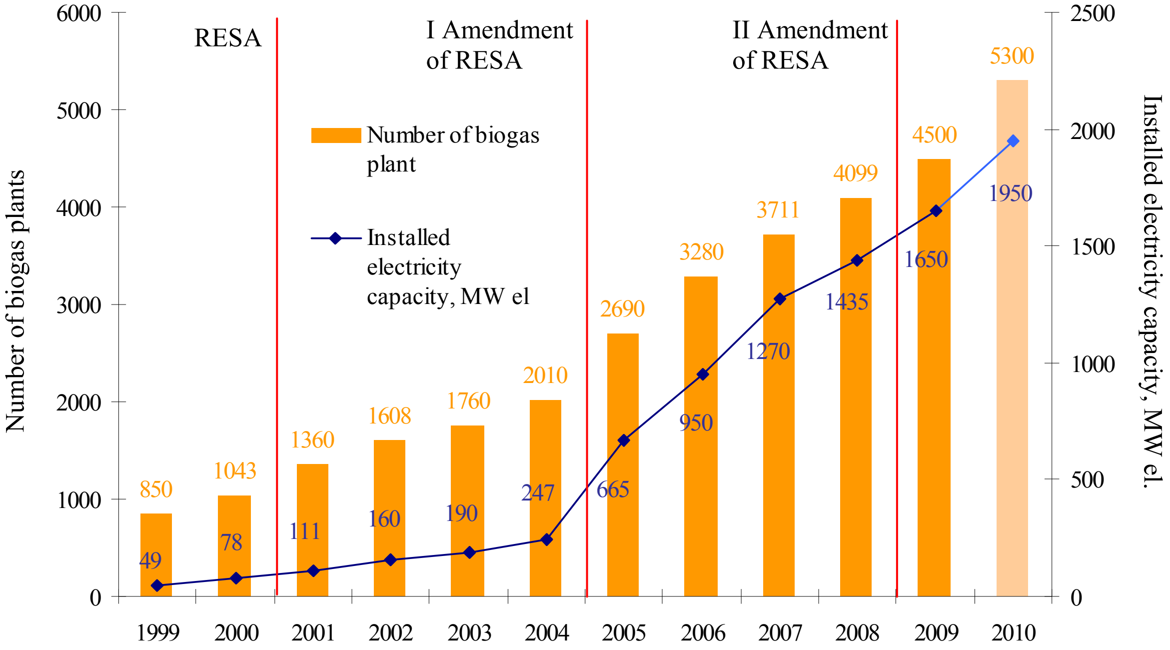
Type of bonus	Year	0-150 KW$_{el}$ (cent/kWhel)	150-500 KW$_{el}$ (cent/kWhel)	500 kW$_{el}$-5 MW$_{el}$ (cent/kWh/el)	>5 MW$_{el}$ (cent/kWh$_{el}$)
Basic	2004	11.5	9.9	8.9	8.4
	2009	11.67	9.8	8.25	7.79
Renewable energy	2004	6	6	4	-
	2009	7	7	4	-
Conbined heat and power plant	2004	2	2	2	2
	2009	3	3	3	2
Technology	2004	2	2	2	-
	2009	2	2	2	-
Animal waste	2009	4	1	1	-
Emission reduction	2009	1	1	1	-
Landscape protection	2009	2	2	2	-

Source: BMU, 2008

Considering Table 2, the basic bonus increased 0.17 cent per kilowatt hour electiricty production for the project category “0-150 kW$_{el}$” for the years 2004 and 2009. For other project categories, the biomass bonus was reduced. The bonus of renewable resource and bonus of CHPP also increased for the projects in categories “0-150 kW$_{el}$” and “150 kW$_{el}$-500 kW$_{el}$” The technology bonus was the same for 2004 and 2009. Finally, the above-mentioned three bonuses would be fulfilled according to the regultions of RESA in 2009 (BMU, 2003 and 2008).

The RESA has made the German biogas scene successful. There was rapid development during the period when the RESA had been amended on two different occasions. The total installed capacity occupies the leading position in the world in terms of biogas electricity projects. Figure 4 explains the number of biogas plants and installed electricity capacity from 1999 to 2010.

Figure 4: Number of biogas plants and installed electricity capacitity



Source: BMU, 2008

In Figure 4, the installed capacity saw rapid development from the year 2005. A prognosis has been made for up to 1,950 MW_{el} of installed capacity with the number of biogas plants in existence being 5,300 by the end of 2010. During the ten-year development, the number of biogas plants increased six times and the installed capacity also increased forty-five times. In this context, compared to China, the flowing differences should be noted: first, the power of the implementation of RESA, second, project planning should be re-considered before project operation and third, there are also different kinds of bonuses to motivate workers in the biogas industry (El-Mashad et al., 2007). Furthermore, energy crops have been planted for many years in Germany (Besgen et al., 2007). The energy crops are good for biogas production, due to their high energy content compared with animal waste. But due to the high population and lack of agricultural lands in China, there is not enough space for the planting of any kind of energy crop for use in the operation of renewable energy projects (MOA, 2008). One of the prime objectives for biogas development in China is to reduce pollution, as well as achieve ecological protection with possible economic benefits.

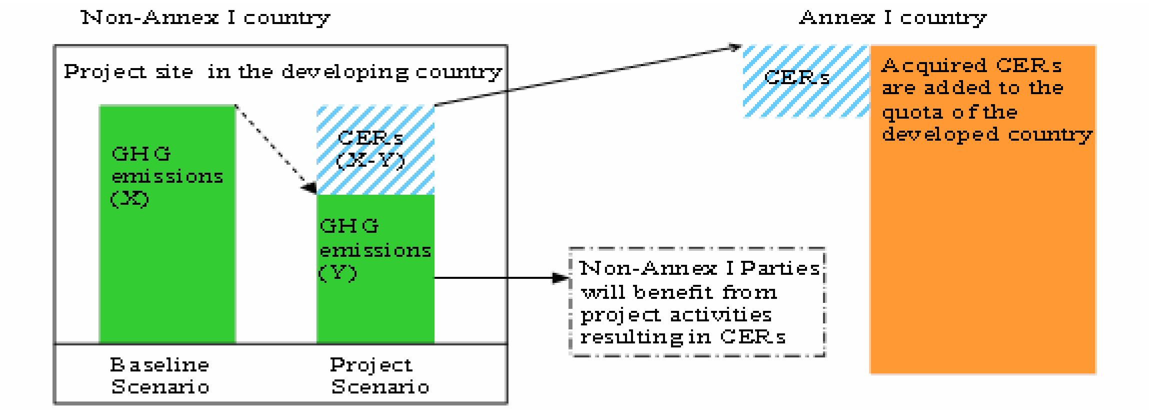
2.2 Kyoto Protocol and Clean Development Mechanism

The implementation of the Kyoto Protocol and CDM is very interested for China's biogas projects. China, as one of the largest countries with GHG emission reduction, has abundant projects working with CDM. Thus, this part will introduce the Kyoto Protocol and CDM, as well as CDM project activities.

2.2.1 General information about Kyoto Protocol and Clean development mechanism

Kyoto protocol includes flexible mechanisms which are Emission Trading, the Clean Development Mechanism and Joint Implementation. The Kyoto protocol allows Annex I countries to make financial decisions to meet their greenhouse gas emission limitations by purchasing GHG emission reductions in non-Annex I countries or from other Annex I countries resulting in the reduction of GHG, purchasing of carbon credits or emission reduction unit (NDRC, 2003). The CDM is an arrangement under the Kyoto Protocol that allows Annex I country with GHG reduction commitment to invest in projects resulting in emission reduction in developing countries as an alternative to more planned emission reductions in their own countries (International conference on Renewable Energy, 2004). The CDM allows emission reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one ton of carbon dioxide. These CERs will be traded and sold (see Figure 5) (UNFCC, 2008).

Figure 5: Diagram of CDM in Kyoto Protocol

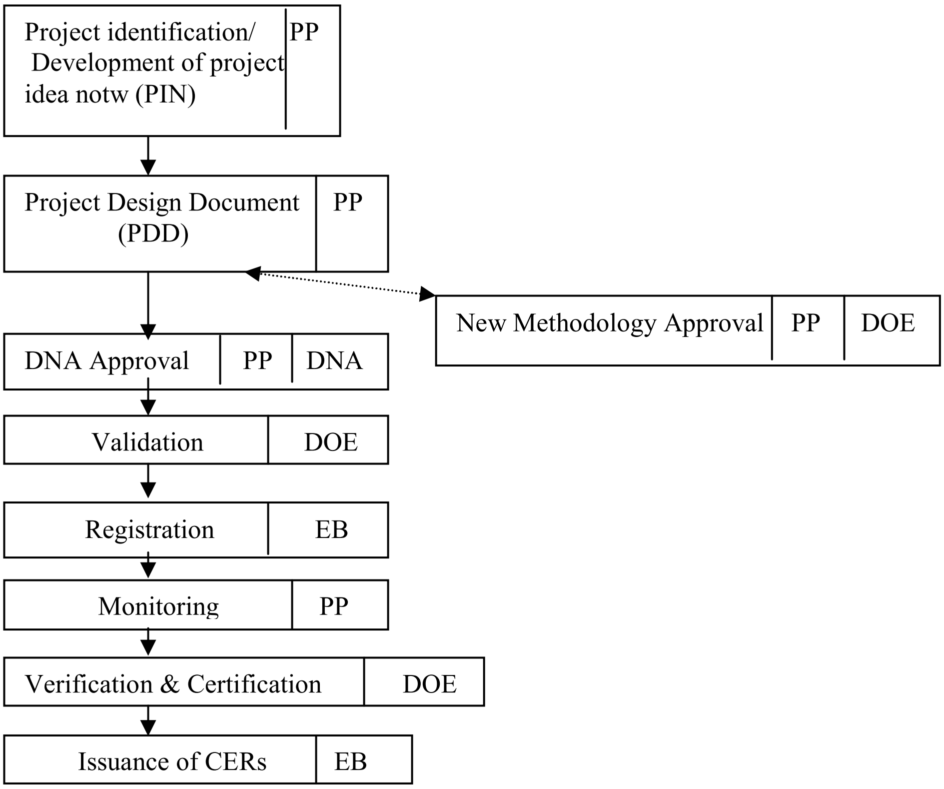


Source: UNFCCC, 2008

The left hand side of Figure 5 shows the activities of non-Annex I countries. The baseline scenario and project scenario should be taken in non-Annex I countries. First, the GHG emissions under the condition of baseline scenario must be estimated (China Coal Information Institute, 2004). Then, the next step is to calculate the GHG emissions in project scenario. The different GHG emissions between baseline and project scenarios mean emission reduction, which can be purchased by Annex I countries. The non- Annex I countries (on the left side of Figure 5) can obtain benefit from project activities resulting in emission reduction. Annex I in this case buy the CERs to fulfil their task under the Kyoto Protocol (IPCC, 2007c and d).

CDM can be likened to a “win-win” situation. But in reality, the CDM project has to go through several steps for it to apply. Thus, the CDM project implementation process can be considered as follows (see Figure 6):

Figure 6: CDM Project Cycle



Source: Ministry of Agriculture (MOA), 2008

As seen in Figure 6, the CDM project cycle involves distinct steps. In general, project proponents (PP) must first identify a project, complete the necessary documentation, obtain host-country approval, and secure project validation by an independent third party (i.e. an accredited Designated National Authority (DNA) (Kyoto Protocol, 1997). If it is necessary, Designated Operating Entity (DOE) should forward the proposed new methodologies and register the project with the Executive Board (EB). Following registration, the project proponent must then monitor project activities and obtain verification of the project's emission reductions by an independent third party. The last step: Submission of the Certification Report to the EB that constitutes the request of CERs (Kyoto Protocol, 1997 and UNFCCC CDM Executive Board, 2002).

Moreover, the forms of financing are very important and must also be implemented based on the CDM project requirements. There are three main different forms of financing for the project implementation. These include unilateral, bilateral, and multilateral forms (Bureau of Commerce of Luzhuo City, 2006). Table 3 indicates the different typs of financing.

Table 3: Mainly financing implementation CDM forms

Form types	Project developer	CERs seller	Risk	Price, \$/t CO_2
Unilateral	Developing country	Developing country	Higher	12-14
Bilateral	Developing and developed countries	Developed country	Lower	8-12
Multilateral	------	"Centralized buying" from more developed countries	Relatively low	-------

Source: China newenergy information, 2007

Unilateral- Owners need to bear their own costs and all pre-registered success of the project risk for the high quality of CDM projects (IGES, 2005). It means the project development is planned and financed within developing country which involves no foreign direct investment. The developing country designs projects and sell certificate autonomously, but the returns and risk are proportional to the benefit from the purchasing of CERs.

Bilateral- The host country and Annex I party representative work together on the project. In doing so, they take some risk with project implementation (UNFCCC, 2008). The developed country can transfer technology and knowledge in project management. The moral authority to sell CERs might belong to the Annex I party. This inherently leads to a lower price, because the investor from Annex I country might have taken some risks.

Multilateral- The CERs generated by the project are sold to a fund which is developed by a "centralized buyer", such as The World Bank Carbon Finance Unit, Netherlands Community Development fund, etc. This kind of funds possesses a specific market skill, ability or context knowledge and more experience which can be used to negotiate better with buyers (UNFCCC, 2008).

After general information about the Kyoto Protocol and CDM, the CDM project activities will be introduced in Chapter 2.2.2.

2.2.2 CDM project activities in China

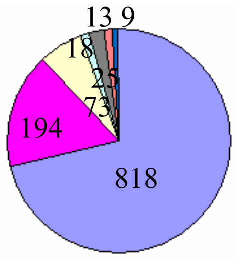
CDM projects distribution

There is a rapid growth in the number of CDM projects both in the registered pipeline and registered at the EB since the beginning of 2006 (CDM in China, 2009). The number of CDM projects in the global carbon market has currently increased sharply. In an international comparison, China's share of the number of projects is about 35% (CDM in China, 2009). However, the Chinese projects are on average larger than those in the rest of the world. According to the United Nations Environment Programme (UNEP) database, by the year 2008, the number of Chinese CDM projects in the pipeline was 1150 and the number of EB registered projects was 352. The annual emission reductions were 332.4 million tons (CDM pipeline statistic, 2009).

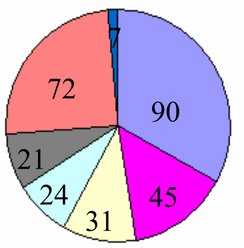
The Chinese CDM projects can be classified into the following ground. It shows in Table 4.

Table 4: CDM project distribution and emission reduction by projects

Number of projects			Amount of ER
818	🟪	New energy and renewable energy	89 934 931
194	🟥	Energy conversation and efficiency	44 967 470
73	🟨	CH_4 recovery and utilization	31 477226
18	⬜	Decomposition N_2O	23 607 919
25	⬛	Substituted fuel	21 247 127
13	🟧	Decomposition HFC23	71 947 944
9	🟦	Others	7 082 375
1150	Total		290 264 990



Number of projects



Amount of ER, million t

Source: ClDM in China, 2009

"New energy and renewable energy" has the largest part. It had 818 projects and the resulting amount of emission reduction of 90 million tons. This means, although "new energy and renewable energy" projects have large amount, the projects have no obvious emission reduction effects (CDM pipeline statistic, 2009). The solar energy, wind power energy and biomass are the main types in this category. Wind powered energy and solar energy are the new energy development focus in the coming years. Currently, China holds the first place of installed electricity capacity for wind powered energy (NDRC, 2009).

"Energy conversion and efficiency" is the next group of large projects. There are totally 194 CDM projects with emission reduction of 45 million tons. Due to the large amount of coal production and consumption in China in recent years, the development focus has been on the utilization of high efficiency of coal concersion, for example, coal bed methane utilization. For the energy efficiency utilization, many departments and companies replace old equipment with new ones. Particularly, some technical transfer with some industrialised countries was made (NDRC, 2009).

The next large project group is "methane recovery and utilization". There are more and more projects with methane recovery, for instance, landfill gas composting and recovery, municipal solid waste gasification, etc The number of projects with methane recovery and utilization was 73, and the amount of emission reduction are 31 million tons (CDM pipeline statistic, 2009).

Thus, the first three types of project have a priority to develop, according the "Criteria for Operation and Management of CDM Projects in China" proposed by National Development and Reform Commission.

Moreover, the projects with decomposition of N_2O, substituted fuel and decomposition HFC23 have been earmarked for development. This is espeically the case for the projects with decomposition of HFC23. Their emission reductions are usually large. Currently, China needs foreign technical support in this very context (IPCC, 2007).

Stakeholders in the China's CDM market

As of the first January 2009, there were over 260 CDM domestic and foreign consulting companies involved in all CDM projects in China. (CDM pipeline statistic, 2009). However, the size and scope of service provided as well as the level of human resource capacity vary substantially across different project developers. Furthermore, many of them, in particular the larger ones, are "multifunctional" in the way that they provide full turn-key service, a comprehensive approach which follows the project from the identification stage of PIN through to PDD writing, project development, monitoring and evaluation, verification and selling of CERs.

A few of the more established European project developers operating in the Chinese CDM market have shared their views. Generally, project developers of the European Union (EU) have expressed some positive views on the current regulatory framework, which is largely seen to facilitate the market in terms of the policy framework in general and CDM policy in particular. Another positive view is that the current CDM market is conductive to the development of new methodologies. Many EU project developers consider new methodologies as a necessity for the further development in the CDM market. As the availability of "bread and butter" projects using established methodologies will decrease, it will become necessary to develop new methodologies for more advanced projects (CDM pipeline statistic, 1 January 2009).

3 Methodologies

In this chapter some methodologies concerning economic and ecological analyses will be introduced.

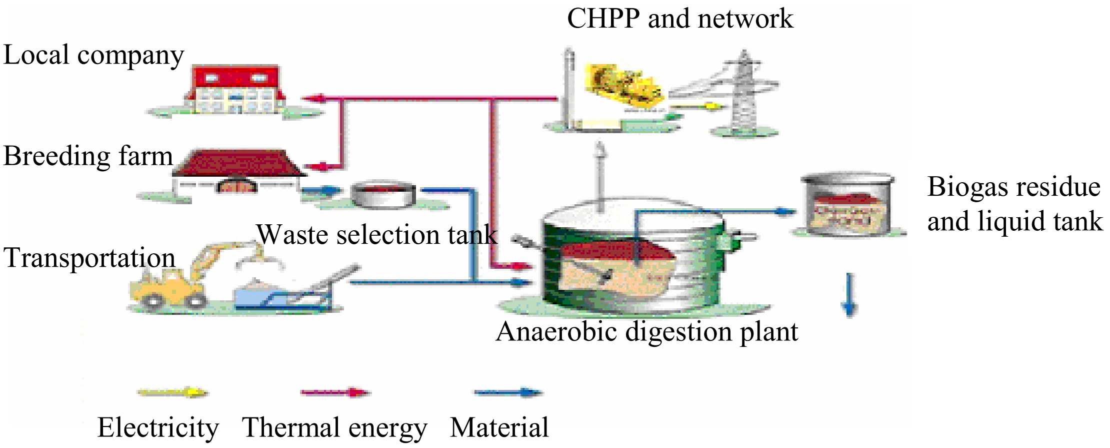
3.1 Economic methodologies

In the following some methodologies concerning economic analyses are presented. These methodologies can analyze the project from different points of view.

3.1.1 Costs-revenue analyses

In China, normally, the biogas production project consists of several parts: the local company, the breeding farm from which the animal waste could be considered as original substrate for biogas production and the transportation site, where the substrate could be transported and saved. The equipment, which is also a component of the system, includes pipelines, the waste selection tank, the anaerobic digestion plant, etc. The most important parts are the anerobic digestion, the combined heat and power plant and the biogas rest tank (residue and liquid). The electricity and heat energy produced could be utilized in local a company for farm production, or the electricity generated could also be transmitted through the national grid. According to the REL, the farmers could obtain a biomass bonus of 0.25 RMB/kWh$_{el}$. from the generated electricity (MOA, 2008). In Figure 7 the biogas project mass flow is indicated.

Figure 7: A flow diagram showing the process of biogas generation and transmission



Source: www.bioenergyGermany, 2008

In this branch of industry a payroll is used to identify all actual performance and associated costs of an expired period. It is important to know which factors influence the efficiency of biogas production. Apart from the fact that the price of electricity could fluctuate on the market, investment needs, gas production, gas quality, operating time duration and CHPP are the more essential factors for computation (Fachagentur Nachwachsende Rohstoffe, 2004).

The next chapter presents the economic analysis of the three biogas projects. The first analysis is of the project involving household thermal energy production and utilization, the second and third are for biogas electricity production for utilization and sale. Concerning the calculation for the projects, the initial, biogas production must be computed considering the different types of substrates. Then, the energy production must also be estimated and separated from electricity production and thermal energy production. After computing the biogas and energy production, the investment costs must be evaluated, which include both construction and equipment. It is very important to compute the revenue and costs for biogas project. The revenue is separated from the sale of electricity, electricity utilization and heat utilization (Friedrichs, Georg, 2005). The costs consist of amortization costs, interest charge, costs of repair, insurance costs, salary, substrate costs, process energy costs and others (Hornbachner et al., 2005). The model for calculation is indicated in Table 5.

Table 5: Calculation model in the three projects

Components	Unit	Project I	Project II	Project III
Substrate	T FM/a			
Pig dung		X		
Dairy cow waste			X	
Chicken dung				X
Biogas production	m^3	X	X	X
Energy production	kWh			
Electricity production			X	X
Thermal energy production		X	X	X
Investment sum	RMB/a			
For fermentation (construction and equipment)		X	X	X
For BHKW (construction and equipment)			X	X
Revenue	RMB/a			
Biomass bonus			-/X	X
From electricity sale			-/X	X
From electricity utilization			X/-	
From heat utilization		X	X	X
Costs	RMB/a			
Amortization		X	X	X
Interests		X	X	X
Repair		X	X	X
Insurance		X	X	X
Salary			X	X
Substrate		X		
Process energy			X	X
Other costs		X	X	X

Source: Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft, 2005

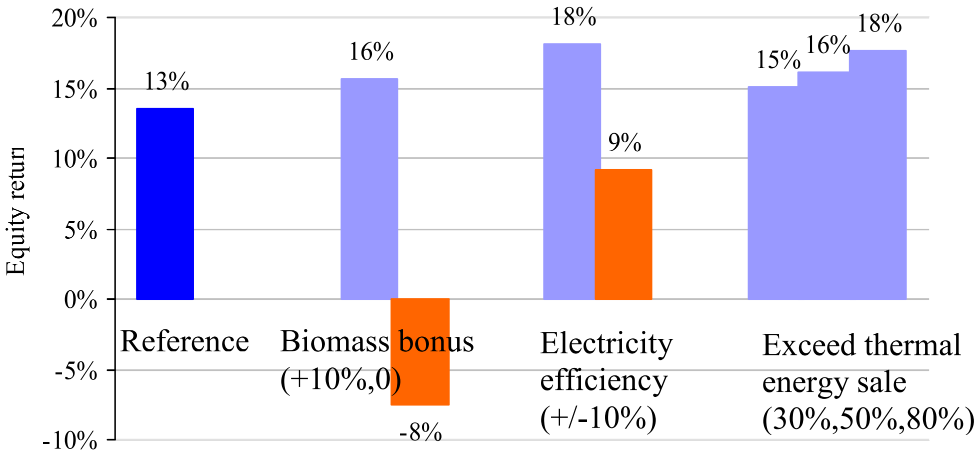
In Table 5, the initial step is to consider the different types of substrates. For project I (see column 3), the substrate was pig dung. The biogas production can also be calculated assessing the dry matter proportion of substrate and methane content. Since the project I is proposed for thermal energy production and utilization, the CHPP in this context is excluded. This explains why the energy production in this context was only thermal energy. Moreover, the investment costs can also be regard as the costs for fermentation and other necessary equipment (stove, pipeline, etc.). The revenue in this case signifies thermal energy production substituted by fossil fuel. The annual costs are also separated from interest charges, amortization costs, costs of repair, insurance costs, substrate costs and other costs (Institut für Energetik und Umwelt GmbH, 2005).

The column 4 shows the biogas project with electricity and thermal energy production. In this context, the substrate used is dairy cow dung (MOA, 2006b). Compared with the first project, the CHPP must be considered. This explains why the energy production included electricity and thermal energy production. This project will be calculated based on two scenarios, for the utilization of electricity locally and for the sale of electricity. When the project estimates for electricity utilization, the revenue from biomass bonus is not considered, and for Scenario II of electricity sale, the revenue of biomass bonus would be regarded (MOA, 2008). For both scenarios, the thermal energy utilization are estimated. The costs of evaluation can be calculated by using the same procedure as for the project I, only, according to the detailed project content, the costs of payment of salaries here will be considered and the substrate costs is regarded as zero. For the third project, the substrate used would be chicken waste. The biogas, energy production, investment costs position and costs calculation section are calculated in the same as in project II. Only, the revenue will be estimated for the sale of electricity with biomass bonus. This project scale was much lager than project II (MOA, 2006b).

3.1.2 Sensitivity analysis

Sensitivity analysis is used to determine how “sensitive” the result in dynamic behaviour is according to the value of parameters. For example, by changing the effectiveness of an intervention by 10%, the cost-effectiveness ratio falls by, for example, 20%. In order to explain the sensitivity analysis, a biogas project was taken as an example (Ma, 2002). Figure 8 indicates the sensitivity analysis for a biogas production project.

Figure 8: Sensitivity analysis

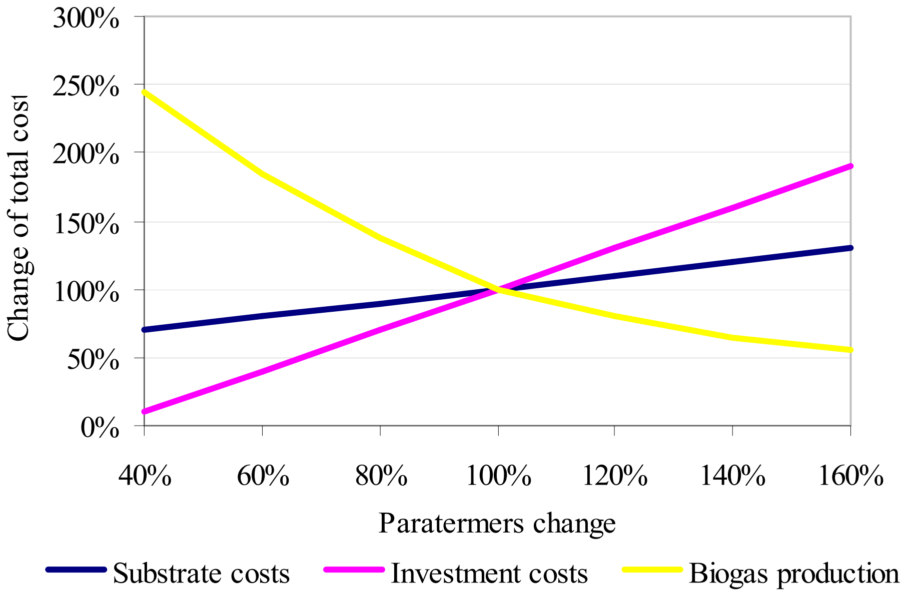


Source: Own interpretation based on the data from Heissenhuber, 2007

As the Figure 8 shows, when the project operates with reference scenario, the equity return is estimated to be 13%. The biomass bonus is a parameter for the project calculation. When the biomass bonus increases 10%, the equity return is evaluated to be 16%, and if the project stakeholder does not obtain the biomass bonus, this project's equity return is -8%. The same is the case for other parameters. All parameters have an effect on project result (Maeng, 1999). Considering the electricity efficiency and thermal energy parameters, if electricity efficiency increases or decreases by 10%, the equity return is computed to be 18% and 9%. If generated thermal energy is sold 30%, 50% or 80% from the entire amount of thermal energy, the equity will be 15%, 16% and 18% (Heissenhuber, 2007).

The sensitivity analysis can also be used when there is a change in the distance parameter. The parameters will be change from the "worst" case and the "best" case. The "worst" and "best" cases values should be chosen from the perspective of the intervention that is being assessed. For example, in one scenario the most optimistic values will be chosen, while in another, the most conservative figure will be used (Mears, 2001). Figure 9 showes sensitivity analysis for biogas project, which illustrates the above mentioned situation.

Figure 9: Sensitivity analsysis



Source: Own interpretation

According to Figure 9, when the substrate costs are changed from 40% to 160%, the total costs change. The total costs are computed from 58% to 130%, which is indicated by the blue line. If the investment costs change from 40% to 160%, consequently, the total costs also change from 20% to 180%. The pink line depicts this. The yellow curve indicates the change in total costs incurred by the change in biogas production. When the biogas production increases from 40% to 160%, the total costs are estimated to be ranging from 245% to 52%.

3.1.3 Break-even analysis

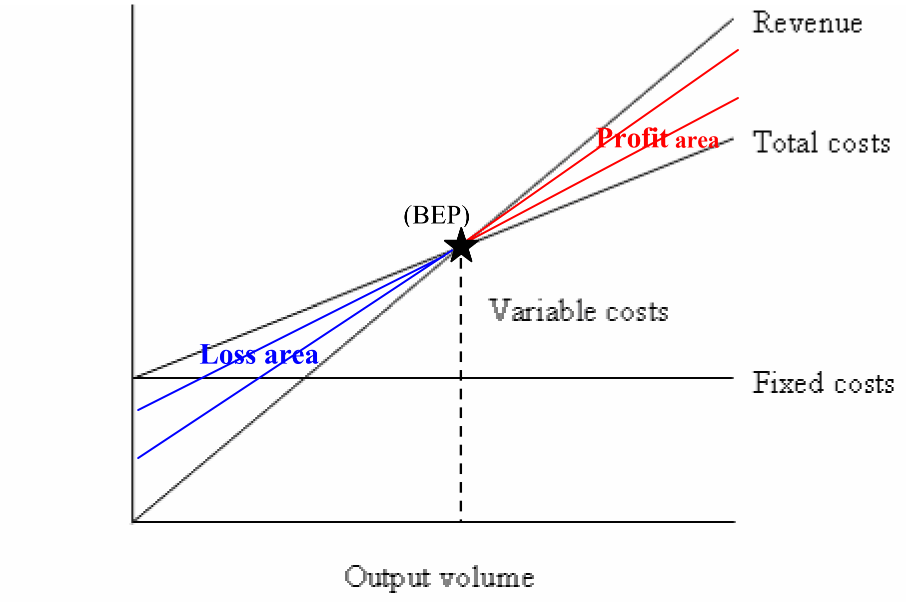
The Break-even analysis for an economic estimation of biogas projects is used to determine the level of profit the project needs to accrue for the efficient operation of the project (Dachverband Agrarforschung, 2006). Three factors needs to be analysed for the Break-even analysis. These factors include: fixed costs, total costs and revenue.

Fixed costs are the costs, like interest charges, amortization costs, insurance costs, and costs of payment of salaries. These costs are not directly related to the level of production or output, even if the biogas project does not operate nor produce high output (FNR, 2004).

The total costs include fixed costs and variable costs. Variable costs will be considered as costs of repair, process energy costs and other costs. Variable costs depend on the project operation (Lusk, 2004). If the project doesn't work, the variable costs will be regarded as zero. If the project operates at 80% capacity related to project reference scenario, the variable costs will be also considered as 80% as in project reference scenario.

Revenue is the project income. The point of intersection of total costs and revenue is a point. This point will be considered as Break-even point (BEP). If the variable costs change, the total costs will be also changed (Roos, 1997b). Then, the Break-even point will also shift. Thus, Figure 10 indicated the Break-even analysis.

Figure 10: Break-even Analysis



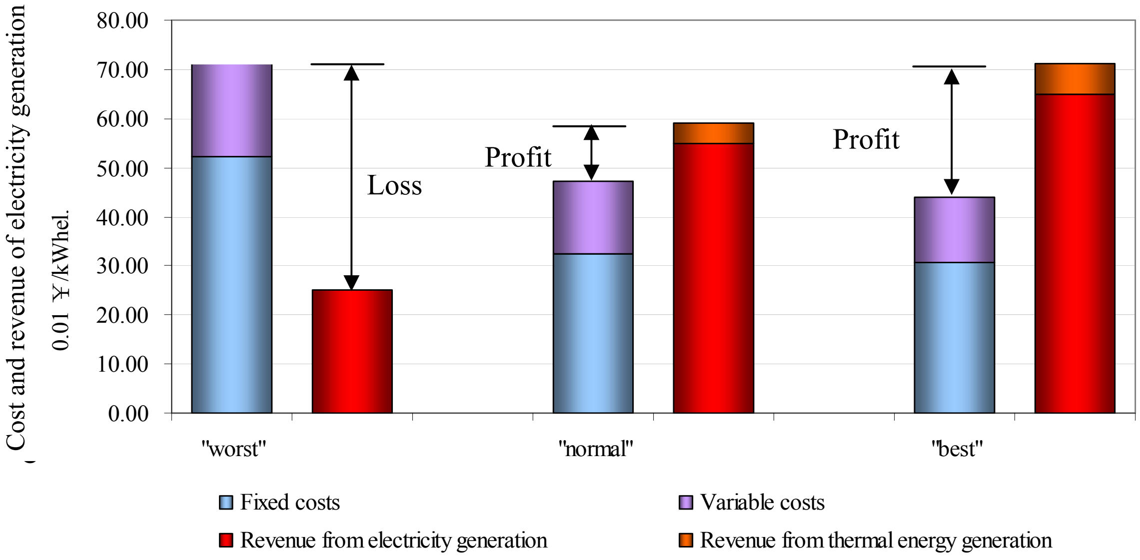
Source: Own interpretation based on the data from FNR, 2004

From above Figure 10, the BEP is the point of intersection of total costs and revenue curves. The right side of BEP indicated profit and the left side- loss. If the total costs or revenue change, the BEP will also be altered.

3.1.4 The "Worst", "normal" and "best" cases analysis

The "worst", the "normal" and the "best" cases can indicate the possible result of the project operation. Thus, when the project operates with the "worst" case scenario, this means, all the parameters stand in the "worst" possible situation. For example, the investment costs are higher than proposed; the costs of payment of salaries increase concerning the market situation; more funds need to be made available for the maintenance of equipment; the biogas produced is less than usual, etc (Hashimoto, 1992). The situation can however be completely the opposite. For example, there will be no need to pay for the substrate. The generated electricity can be sold to the national network and the stakeholder obtains the biomass bonus, leading to an increase in biomass bonus; etc. In that context, the stakeholder should know which situation needs to be avoided, and which moment required attention (Converse, 2001). Figure 11 is taken as an example of a biogas project, to show how the project with the "worst", the "normal" and the "best" cases operated.

Figure 11: The „worst", the „normal"and the „best"cases



Source: Own interpretation based on the data from Prof. Heissenhuber, 2007

In Figure 11, the fixed costs[2] and variable costs[3] are estimated in all three cases. Thus, the difference in these three cases can be clearly described.

3.1.5 Cash flow and liquidity

Cash flow refers to the movement of cash into or out of a business, a project, or a financial product. A cash flow forecast helps the stakeholder estimate how much money can be spent today for instance without running out of cash unexpectedly (Price, 1981). In order to calculate the cash flow and liquidity, the annual income and outcome must be considered.

---

[2] Fixed costs included interest charges, amortization costs, costs of insurance, costs of payment of salaries.

[3] Variable costs included costs of repair, substrate costs, process energy costs and other costs.

The calculation of liquidity could be considered using the formula indicated below. Table 6 indicates the cash flow and liquidity.

Table 6: Cash flow and liquidity for a biogas project

Income	Year 0	Year 1	Year …	Year n
- electricity sale - thermal energy utilization - carbon market				
Outcome				
- Interest charges - Costs of repair - Insurance costs - Costs of payment of salaries - Process energy costs - Substrate costs - Other costs				
Cash flow before interest				
Cash flow after interest				
Net present value				
Liquidity before interest				
Liquidity after interest				

Source: Own interpretation based on data from Heissenhuber, 2007

The annual project income for the biogas project includes normally the income from the sale of electricity, thermal energy and carbon trade. The annual outcome is considered as interest charges, costs of repair, insurance costs, costs of payment of salaries, process energy costs, substrate costs and other costs (Oregon Office of Energy, 2000). Cash flow before interest is the sum of the annual income and the outcome of the project. For cash flow after calculating interest, the bank loan must be considered. Then, the net present value could be evaluated[4]. The liquidity before and after interest, is the sum of cash flow before (after) interest of the previous years and the current year.

3.1.6 Monte-Carlo-Simulation

The Monte Carlo method or a random computer simulation is based on a “random number” calculated system. This approach originated from the United States and was used to develop

---

[4] NPV= $\frac{R_t}{(1+i)^t}$, where, NPV- net present value; t- time of the cash flow; i- discount rate; R_t- cash flow.

the atomic bomb “Manhattan Project” in the II World War. A well-known mathematician Neumann named this mysterious method as Monte- Carlo (Rauh et al., 2008).

For biogas plants, there is viability of numerous parameters for an existing or planned biogas calculation: on the one hand, equipment capability, performance of combined heat and power plant (CHPP), the total investment, etc (Kobzar, 2006). On the other hand, the substrate yield or other unknown factors, such as achieved CHPP efficiency or degradation rate in fermentation must be considered.

The Monte-Carlo-Simulation method for biogas projects evaluation can be realized by the following actions:

- The first is model construction. The input parameters should be defined and denominated for step forward programming. In this context, three scenarios must be identified: minimum, maximum and model (Anton, 2005). This means that all data for an economic calculation has to be qualified within an alterable scope and the probability mass function ought to be disposed of. For example, the investment costs will fluctuate between a variance of +5% and -5% variance. This step can be named instituted “Original Data Pre-arrangement”.
- The “Outcomes Classification in a Matrix” is the second step. Considering this step, five factors should be listed: Lower Limit, Upper Limit, Planned Value, Modulus[5] and Step size[6] (Frühwirth, 1983). If the number of class were defined by 100 and 1000 number test run will be hypothesized[7], the outcome will form a 1000 x 100 matrix. Moreover, some results of an experiment must be provided, for the biogas project, they include subsequent interesting findings: total energy production; net power production; heat production; total costs; revenue; profit, etc (KTBL, 2006).
- “Risk analysis” is the next important step, in instead of the estimation, the above-mentioned deliverables should be applied, besides, the future estimated factors and theirs required parameters (minimum, maximum and model). The matrix should also be created to run the programme[8]. Furthermore, the number of test run will be defined or can be also redefined concerning the analysis demand (Richardson et al., 2006). Two knobs are necessarily knob knotting: risk analysis starting and box information emptying.

---

[5] It is the difference between Upper and Lower Limits value;

[6] It is the Upper Limit divides into 100 (class numbers).

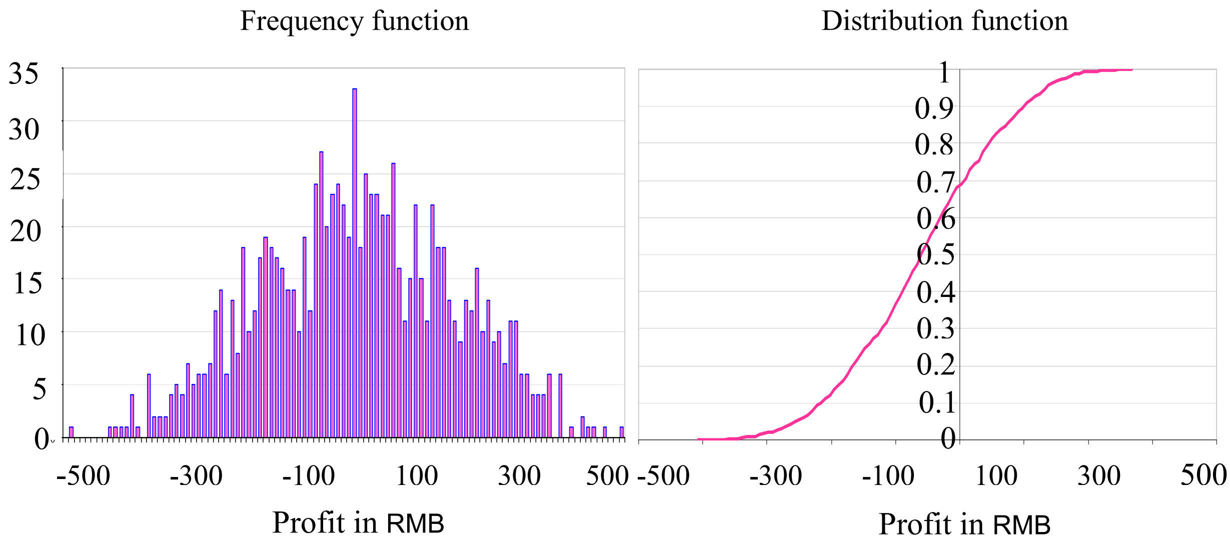
[7] This number should be defined in next step.

[8] This matrix will be formed as 1000 x interested required findings.

- After three predetermined programming action, "The Density function" and "Distribution Function" appear after having provided results of experiment (in step two) and analysis starting knob knotting (in step three). An example of results from the Monte-Carlo-Simulation is illustrated in Figure 12 and 13. After 100 simulation runs Figure 12 (left) presents the frequency distribution for the mapped profit. For displaying the frequency distribution in Figure 1, the simulation gains in the rage of -500 to 750 divided by 100 class numbers 1,000 RMB. An analysis of frequency distribution shows, in which spectrum the profit can be located (Bahrs, 2002). Likewise, this analysis can be read off the area, in which the simulated profit is more available. From this Figure can be seen that the range is obtainable between -600 and 700 RMB. The planned static value (about 33 RMB) is located on the right edge of this high plateau.

Thus, the frequency and distribution function are indicated in Figure 12.

Figure 12: An example of frequency and distribution function


Frequency function

Distribution function

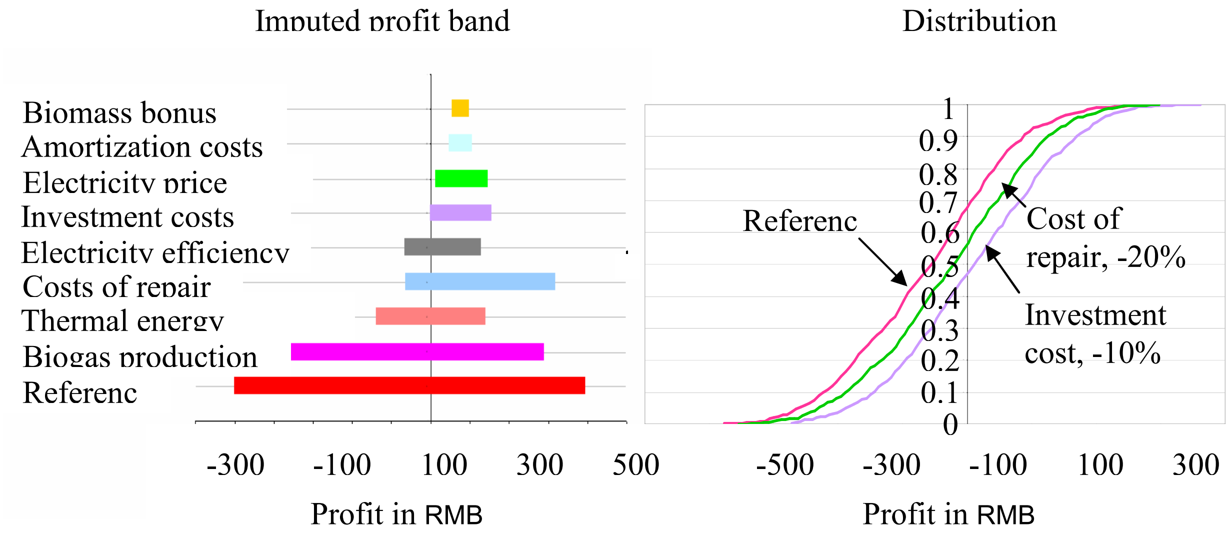
Source: Own interpretation based on the data from Rauh, 2008

As seen in Figure 12 on the left, there is frequency function of biogas project. The highest value of this project is 33 RMB. The profit is estimated from -600 RMB to 700 RMB.

From the Figure 12 (right) the biogas plant operator can aware of upper and lower limit of the simulated values in the biogas project. Concurrently however, the operator notes that their extreme events with only minimal likelihood occur (Rauh, 2008). Continuously, the results indicate negative profit, so a loss acts officially at 68% (at the intersection of the curve with the y-axis). The planned profit achieved is with the probability of 32%.

Every parameter has more or less an influence on the final result. The Monte-Carlo-Simulation can show the result, when only one factor changes and the others parameters stand by constants. In Figure 13 the left side indicates the bandwidth of the profit in the simulation of individual variables. Moreover, this can be also shown by distribution function (Rauh, 2008). In Figure 13 the right side indicates the change in the distribution function by optimizing operation.

Figure 13 Bandwidth of the profit in the simulation of individual variables and change in the distribution function by optimizing operation



Source: Own representation based on the data from Rauh, 2008

In Figure 13, on the left hand side bandwidth of the profit in the simulation of individual variables is indicated. The result is estimated to be from -300 RMB to 400 RMB in reference scenario. When the parameter of biogas production changed, the profit is from -150 RMB to 280 RMB. The same situation occurred with every parameter change, for instance, thermal energy utilization, costs of repair, electricity efficiency, investment costs, electricity price, amortization costs, biomass bonus, etc. In this context, the profit changed with the variation of the parameters, and the profit was evaluated differently (KTBL, 2004). So, as a result, biogas production was the most sensitive parameter for this example, and the parameter of the biomass bonus has less effect on the profit.

In Figure 13 on the right side, this is changed in the distribution function by optimizing operation. The profit, considering the reference scenario under the distribution function is the red curve. The project has only 32% to accrue profit. When the parameter of costs of repair decreased 20%, the curve moved on the right, and the project had 42% to accrue profit. This is shown in green curve. When the parameter of investment costs decreased 10%, the project had more than 50% to accrue profit, and this is showed in the violate colour.

3.2 Ecological methodologies

Ecological methodologies will be presented concerning the field of CDM. First, two methodologies for GHG emission reduction will be introduced. Then the method for analysing costs of GHG emission reduction will also be described.

3.2.1 Consolidated baseline methodology for GHG emission reductions from manure management systems

The CDM is a mechanism where Annex 1 countries with a specific obligation to reduce a set amount of GHG emissions by 2012 under the Kyoto Protocol assist non- Annex 1 countries to implement project activities to reduce or absorb (sequester) at least one of six GHGs (IPCC, 2007). Non-Annex 1 countries are signatories to the Kyoto Protocol; however, they do not adhere to reduction targets stipulated under the protocol. The reduced amount of GHGs gets credits, the so called certified emission reductions (CERs) which Annex 1 countries can use to help meet their emission reduction targets under the protocol (UNFCCC, 2008).

The “Consolidated baseline methodology for GHG emission reductions from manure management systems (ACM0010)” from “Methodologies for CDM project activities” (UNFCCC, 2008) should be used for the analysis of GHG emission reductions in this paper. This consolidated baseline methodology is based on elements from the the so called methodologies are AM0006 and AM0016. (UNFCCC 2008). The ACM0010 is applicable generally to manure management on livestock farms where the existing anaerobic manure treatment system, within the project boundary, is replaced by one or a combination of more than one animal waste management system (AWMs) that result in less GHG emission (IPCC, 2007b). And there are following conditions for manure management projects:

- ✓ Farms should be under confined livestock populations, comprising of cattle, buffalo, swine, sheep, goats, and poultry;
- ✓ Farms manure must not be discharged into natural water resources;
- ✓ The depth of anaerobic lagoons should be at least one meter under the baseline scenario;

- ✓ The baseline site for anaerobic manure treatment facility should be higher than 5 degrees;
- ✓ The lagoon should have a non-permeable layer at the lagoon bottom and the anaerobic treatment system for manure waste retention time should be greater than one month.

The methodology confirms the baseline scenario through the following four steps (UNFCCC, 2008). The first, alternative scenarios should be defined for the proposed project activity. They must not be registered as a CDM project; however, they are presented for project manure managing development (step 1). The second, some kind of investment, technological and other barriers can be precluded from selected scenarios to take place in the absence of CDM. Therefore, these series of barriers should be listed (step 2). The next, the economic comparison should illustrate the competitive strength of the different scenarios (baseline and alternatives). Here, the calculation must include an internal rate of return (IRR) and net present value (NPV) analysis (step 3). The last step is the baseline revision at the crediting period regeneration, then the DOE undertakes assessment, if there is an account change identified between two crediting periods (step 4) (UNFCCC, 2008).

For step one, the proposed project activity not being registered as a CDM project activity and all other possible alternatives scenarios for AWMs should be taken into account. Moreover, the identifying alternative scenarios should have been implemented previously or currently underway (IPCC, 2007 a).

There are three different types of barriers which must be analysed in the absence of the CDM for step two: investment barriers; technological barriers and barriers due to prevailing practice. The investment barrier should check that debt funding is not available for the project activity and that is the reason why this project cannot be implemented. In some developing countries, there is a lack of infrastructure for implementation which the project should also document (UNFCCC, 2008). For the barriers due to prevailing practice, the alternative is the “first of its kind”. It means there is no alternative which is currently operational in the proposed project region.

For each investment analysis alternative scenario, all costs and economic benefits should be illustrated in comprehensive manner, as shown in Table 7.

Table 7: Calculation of NPV and IRR

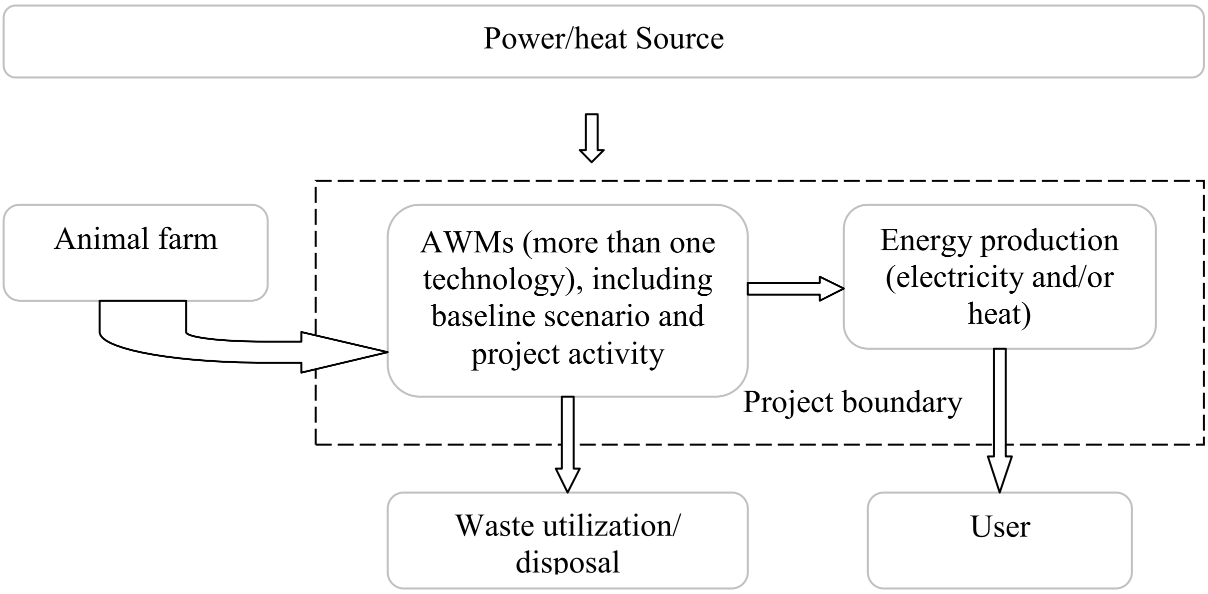
Costs and benefits	Year 1	Year 2	Year 3	Year 4
Equipment costs				
Installation costs				
Maintenance costs				
Other costs				
Revenues from the sale of electricity or other project related products, when applicable				
Subtotal				
Total				
NPV				
IRR (%)				

Source: UNFCCC, 2008

The IRR and the NPV should be calculated for each alternative baseline scenario. There are several elements which must be included in the calculation: investment costs, operating and maintenance costs revenue from the sale of electricity, as well as any other appropriate costs. And the last step is the baseline revision at the extension of the crediting period. This is what a renewal of the crediting period involves, the project participants should take into account change and identify two crediting periods as well as any increase in the animal stock.

The project boundary should be defined for emission sources and gases description for baseline and project activity. The project activity boundary is shown clearly in the following flow chart (CDM in China, 2009).

Figure 14: Project activity boundary



Source: UNFCCC, 2008

The source from the baseline should be included: direct emission from the waste treatment processes, emission from electricity consumption/generation and emission from thermal energy generation. These gases mainly consist of CH_4, N_2O and CO_2 (UNFCCC CDM Executive Board, 2002).

For the baseline scenario, the direct emission from the waste treatment processes should be taken into account for, e.g. of CH_4 and N_2O, of which CH_4 is the major source of emissions in the baseline and N_2O emission from open anaerobic lagoon (UNFCCC CDM Executive Board, 2004a); whereas in emissions from electricity consumption/ generation is only appeared CO_2, as a result of consumption of electricity and/or heat from the grid or generated onsite in the baseline scenario (Delhotal, 2006).

The project activity must include subsequent steps: emission from thermal energy generation from local electricity use and then the direct emissions from the waste treatment processes. During the thermal energy generation, CO_2 may be an important emission source, and if electricity is generated from biogas, these emissions are not accounted for. Like in the baseline scenario, there are two gases, CH_4, N_2O must be accounted for the direct emissions from the waste treatment processes (UNFCCC CDM Executive Board, 2005b).

Emission reduction

The emission reduction ER_y by the project activity during a given year y is the difference between the baseline emissions (BE_y) and the sum of project emissions (PE_y) and leakage, as follows (UNFCCC, 2008):

$$ER_y = BE_y - PE_y - LE_y$$

Baseline Emissions

The baseline is the AWMs identified through the baseline selection procedure.

Baseline emissions are:

$$BE_y = BE_{CH_4,y} + BE_{N_2O,y} + BE_{elec/heat,y}$$

Notes:

BE_y *:Baseline emissions in year y, in* tCO_{2e}/a

$BE_{CH_4,y}$ *:Baseline methane emissions in year y, in* tCO_{2e}/a

$BE_{N_2O,y}$ *:Baseline* N_2O *emissions in year y, in* tCO_{2e}/a

$BE_{elec/heat,y}$ *:Baseline* CO_2 *emissions from electricity and/or heat used in the baseline, in* tCO_{2e}/a

For the baseline emissions calculation, two formulae must be considered here. The first is the form for the baseline methane emissions calculation. Thus, the first form for $BE_{CH_4,y}$ can be evaluated with the formulae below (UNFCCC, 2008):

$$BE_{CH_4,y} = GWP_{CH_4} * D_{CH_4} * \sum_{j,LT} MFC_j * B_{o,LT} * N_{LT} * VS_{LT,y} * MS\%_{BL,j}$$

Where, $VS_{LT,y} = \left(\frac{W_{site}}{W_{default}} \right) * VS_{default} * nd_y$

Notes:

GWP_{CH_4} *: Global Warming Potential (GWP) of* CH_4 *that equals to 21*

D_{CH_4} *:* CH_4 *density that equals to 0.00067t/*m^3 *at room temperature of 20°C and 1 atm pressure*

$\sum_{j,LT} MFC_j$ *: Annual methane conversion factor for the baseline AMWS from IPCC 2006 (Table 10.17)*

$B_{o,LT}$ *: Maximum methane producing potential of the volatile solid generated*

N_{LT} *: Average of animal amount for the baseline and the project cases emissions reduction*

$VS_{LT,y}$ *: Annual volatile solid for livestock that can be calculated with the difference between the average animal weight in the project and default average of, the animal weight, then multiply the default value for the volatile solid excretion on dry matter, and multiply 365 days'*

$MS\%_{BL,j}$ *: Fraction of manure handled that equals to 100%*

The second formulae for the baseline nitrous oxide calculation, which can be estimated using the formula below (UNFCCC, 2008):

$$BE_{N_2O,y} = GWP_{N_2O} * CF_{N_2O-N,N} * \frac{1}{1000} * \left(E_{N_2O,D,y} + E_{N_2O,ID,y} \right)$$

Where $E_{N_2O,D,y} = \sum_{j,LT} \left(EF_{N_2O,D,j} * NEX_{LT,y} * N_{LT} * MS\%_{Bl,j} \right)$

$$E_{N_2O,ID,y} = \sum_{j,LT} \left(EF_{N_2O,ID,j} * F_{gasm} * NEX_{LT,y} * N_{LT} * MS\%_{BL,j} \right)$$

$$NEX_{LT} = \frac{TAM}{1000} * NEX_{IPCCdefault} * 365$$

Notes:

GWP_{N_2O} *: Global Warming Potential (GWP) of* N_2O *that equals to 310*

$CF_{N_2O-N,N}$ *: Conversion factor* N_2O*-N to* N_2O *that equals to 44/28*

$EF_{N_2O,D,y}$ *: Direct* N_2O *emission in kg* N_2O*-N/kg N/a*

$NEX_{LT,y}$ *: Annual average nitrogen excretion per head of a defined livestock population in kg/N animal/a*

$MS\%_{Bl,j}$ *: Fraction of manure handled in system j, in %.*

N_{LT} *: Annual average number of animals*
$EF_{N_2O,ID,y}$ *Indirect N₂O emissions in kg N₂O-N/kg N/a*

Furthermore, the last step for baseline carbon emission estimation would be the calculation of $BE_{elec/heat,y}$. The formula shows below:

$$BE_{elec/heat,y} = EG_{Bl,y} * CEF_{Bl,elec,y} + EG_{d,y} * CEF_{grid} + HG_{Bl,y} * CEF_{Bl,th,y}$$

Where,

$EG_{Bl,y}$ *: The amount of electricity which consumed at the project site without the project activity*
$CEF_{Bl,elec,y}$ *: The factor of carbon dioxide for electricity consumed at the project site*
$EG_{d,y}$ *: The amount of electricity utilization for the biogas collected during the project activity and exported to the grid*
CEF_{grid} *: The factor of carbon dioxide for the grid in the project activity*
$HG_{Bl,y}$ *: The amount of thermal energy utilization by using fossil fuel at the project site in absence of the project activity*
$CEF_{Bl,th,y}$ *: The carbon dioxide intensity for thermal energy generation*

Project Emissions

The project activity might include one or more AWMs treating the manure. The project emissions must be calculated based on the sum of the leakage from AWMS systems that capture's methane in tCO_{2e} per year ($PE_{AD,y}$); the methane emissions from AWMS that aerobically treats the manure in tCO_{2e} per year ($PE_{Aer,y}$); the nitrous oxide emission from project manure waste management system in tCO_{2e} per year ($PE_{N_2O,y}$), the physical leakage of emissions from biogas network to flare the captured methane or supply to the facility where it is used for heat and/or electricity generation in tCO_{2e} per year ($PE_{PL,y}$), the project emissions from flaring of the residue gas stream tCO_{2e} per year ($PE_{flared,y}$) and project CO_2 emissions from electricity and/ or heat used in the project activity in tCO_{2e} per year ($PE_{elec/heat,y}$), which is indicated using the formula below;

$$PE_y = PE_{AD,y} + PE_{Aer,y} + PE_{N_2O,y} + PE_{PL,y} + PE_{flared,y} + PE_{elec/heat,y}$$

Where,

$$PE_{AD,y} = GWP_{CH_4} * D_{CH_4} * LF_{AD} * F_{AD} * \sum_{LT} \left(B_{o,LT} * N_{LT} * VS_{LT,y}\right)$$

$$PE_{Aer,y} = PE_{Aer,tr,y} + PE_{Sl,y}$$

$$= GWP_{CH_4} * D_{CH_4} * 0.001 * F_{Aer} * \left[\prod_{n=1}^{N} \left(1 - R_{VS,n}\right) \right] * \sum_{j.LT} \left(B_{0,LT} * N_{LT} * VS_{LT,y} * MS\%_j\right) +$$

$$GWP_{CH_4} * D_{CH_4} * MCF_{sl} * F_{Aer} * \left[\prod_{n=1}^{N} \left(1 - R_{VS,n}\right) \right] * \sum_{j.LT} \left(B_{0,LT} * N_{LT} * VS_{LT,y} * MS\%_j\right)$$

$$PE_{N_2O,y} = GWP_{N_2O} * CF_{N_2O-N,N} * 0.001 * EF_{N_2O,y} * NEX_{LT,y} * N_{LT}$$

Notes:

$PE_{PL,y}$ *This is the sum of the quantities of captured methane fed to the flare, to the power plant and to the boiler... In the case where biogas is just flared and the pipeline from collection point to flare is short less than 1 km, and for on site delivery only, one flow meter can be used. In such cases the physical leakages may be considered as zero.*

$PE_{flared,y}$ *Due to biogas captured is used for power generation, these emissions from flaring of the residue gas stream are not accounted for.*

$PE_{elec/heat,y}$ *This is the sum of project emissions from electricity and heat use.*

LF_{AD}*: Methane leakage from anaerobic digesters with default 0.15*
F_{AD}*: Fraction of volatile solid directed to anaerobic digester*
F_{Aer}*: Fraction of volatile solid directed to aerobic system*
$R_{vs,n}$ *Fraction of volatile solid degraded in AWMS treatment method n of the N treatment steops prior to waste being treated in aerobic lagoon*
MCF_{sl} *Methane conversion factor (MCF) for the sludge stored ponds*
$E_{N_2O,y}$ *The sum of direct and indirect emission factor*

Leakage

Leakage covers the emissions from land application of treated manure, outside the project boundary. The leakage is the difference between the leakage emissions released in project activity and those released in the baseline, which can be calculated with the formula

$$LE_y = \left(LE_{P,N_2O} - LE_{B,N_2O}\right) + \left(LE_{P,CH_4} - LE_{B,CH_4}\right)$$

Where,

$$LE_{P,N_2O} = GWP_{N_2O} * CF_{N_2O-N,N} * 1/1000 * \left(LE_{N_2O,land} + LE_{N_2O,runoff} + LE_{N_2O,vol}\right)$$

$$LE_{B,N_2O} = GWP_{N_2O} * CF_{N_2O-N,N} * 1/1000 * \left(LE_{N_2O,land} + LE_{N_2O,runoff} + LE_{N_2O,vol}\right)$$

$$LE_{P,CH_4} = GWP_{CH_4} * D_{CH_4} * MCF_d * \left[\prod_{n=1}^{N} (1 - R_{VS,n}) \right] * \sum_{j,LT} (B_{o,LT} * N_{LT} * VS_{LT,y} * MS\%_j)$$

$$LE_{B,CH_4} = GWP_{CH_4} * D_{CH_4} * MCF_d * \left[\prod_{n=1}^{N} (1 - R_{VS,n}) \right] * \sum_{j,LT} (B_{o,LT} * N_{LT} * VS_{LT,y} * MS\%_j)$$

Notes:

$CF_{N_2O-\ N,N}$: *Conversion factor equals to 44/28*

$LE_{N_2O,land}$: *Direct nitrous oxide emissions from application of manure waste*

$LE_{N_2O,runoff}$: *Nitrous oxide emissions due to leaching and run-off*

$LE_{N_2O,vol}$: *Nitrous oxide emissions from atmosoheric deposition on soils and water surfaces*

3.2.2 Methane recovery in agricultural activities at household/small farm level

The methodology is amid to the project which demonstrates technical approaches and a credible carbon trade process for a household-based/ small famers CDM biogas digester program. The original wastes from people and/ or animal manures should be operated into biogas digesters, this project will reduce the GHG, and improve the local rural environment and household living conditions (IPCC, 2007).

Compare to the "consolidated baseline methodology for GHG emission reductions from manure management system", this methodology comprises recovery and destruction of methane from manure and wastes from agricultural activities that would be decaying anaerobically emitting methane to the atmosphere in the absence of project activity (IPCC, 2007b). This methodology is limited for individual households or small farms, where their annual emission reduction must be not more than 5 tons of CO_{2e}. The project condition must be contributed (a) the anaerobic digestion must be handled, and in case of final sludge for land application, the conditions must be ensured that there are no methane emissions; (b) this application form shall be used for combustion or burn in a biogas burner for cooking needs.

In the baseline scenario, the methane is emitted to the atmosphere in absence of project activity, in baseline scenario emissions are calculated in amount of using waste that would decay an aerobically in the absence of the project activity, which is determined by survey of a sample group of household/ small farms with a confidence level of 95%, by which should be determine the baseline animal manure management practices applied (CDM in China, 2009). If the methane recovery and combustion equipment is transferred from another activity, leakage is to be considered.

The monitoring plan and the form for emission reduction can be achieved by using the consolidated baseline methodology for GHG emission reductions from manure management systems. Thus, the calculation GHG emission reduction is the important content for CDM project implementation. After determination of the baseline scenario and the project acticity, next, the BE_y and PE_y must be analysed, as well as ER_y .Concerning the methodology, BE_y and PE_y must be determined. ER_y is the difference in BE_y and PE_y . Thus, for some Chinese projects, before biogas digesters installed, the rural farmers used coal as resource to get thermal energy. After biogas digesters installation, farmers have used generated thermal energy from biogas, as well as also some coals. In view of that, the BE_y and PE_y will be estimated from two parts. There are the methane emissions from manure and the carbon dioxide emissions from coal consumption (UNFCCC, 2008).

Baseline emissions

Thus, BE_y as the methodology showed, include baseline methane emissions from manure management system (I) and the baseline carbon dioxide emissions from coal consumption (II), which is indicated using the formula below:

$$BE_y = BE_{CH_4B} + BE_{CO_2C}$$

Where,

$$BE_{CH_4B} = GWP_{CH_4} * \frac{1}{1000} * LN_{i,k} * EF_i$$

$$= GWP_{CH_4} * \frac{1}{1000} * LN_{i,k} * (VS * 365) * \left[B_o * D_{CH_4} * \sum_j \frac{MCF_{ij}}{100} * MS_{ij} \% \right]$$

$$BE_{CO_2C} = C_{\cos um.b} * EF_{cc}$$

$$= C_{\cos um.b} * EF_{rawcoal} * C_{nv} * 44/12$$

Notes:

EF_i : *Tthe methane emission factor for deep pit swine manure management in county I*

VS : *The daily volatile solid excreted for swine*

Bo : The maximum methane producing capacity for manure produced by swine

D_{CH_4} *Methane density (0.00067 t/m*^{3} *at room temperature 20°C and 1 atm pressure)*

MCF_{ij} *The methane conversion factor for deep pit manure management*

MS_{ij} : *The fraction of swine handeld in system j*

$C_{\cos um.b}$: *The average of coal consumption before biogas plant installed*

EF_{cc} : *The emissions factor of coal combustion*

$EF_{rawcoal}$ *is 25.8 tC/TJ*

C_{nv} : *The Net calorific value, equals to 20908 kJ/kg*

44/12 : The ratio of the molecular weight ratio of carbon dioxide to carbon is 44/12

Project acticity

PE_y are also sepearted from emissions from methane emissions and coal consumption. In this context, the default number after field research can be taken for project methane emissions from each of digester. For project carbon dioxide emissions from coal consumption calculation, the emission factor of coal combustion (EF_{cc}) must be considered, asd well as the average of coal consumption after digesters installation. PE_y can be evaluated with the formula below (UNFCCC, 2008):

$$PE_y = PE_{CH_4B} + PE_{CO_2C}$$

Where

$$PE_{CO_2C} = C_{consum,a} * EF_{cc}$$

Notes:

PE_{CH_4B} is the project methane emissions

$C_{consum,a}$ ist he average of coal consumption after biogas plant installed

EF_{cc} is the emissions factor of coal combustion

Emission reduction

$$ER_y = BE_y - PE_y$$

3.2.3 Costs of CHG emission reduction

The costs of GHG emission reduction can be considered in the formula below:

$$C_{GHG,ED} = \frac{(C_{biogas,el} - C_{biogas,th}) - C_{coal,el}}{(GHG_{biogas,el} - GHG_{coal,th}) - GHG_{coal,el}}$$

Notes:

$C_{GHG,ED}$ *:Costs of GHG emission reduction*

$C_{biogas,el}$ *:Costs of electricity generation in biogas project*

$C_{biogas,th}$ *:Costs of thermal energy generation in biogas project*

$C_{coal,el}$ *:Costs of electricity generation in coal consumption*

$GHG_{biogas,el}$ *:GHG emission from electricity generation in biogas project*

$GHG_{coal,th}$ *:GHG emission from thermal energy generation in coal consumption*

$GHG_{coal,el}$ *:GHG emission from electricity generation in coal consumption*

Source: Own representation based on data from CDM, 2006

From the formula, first the calculated costs for electricity generation in biogas can be analysed. These costs are different from the costs of electricity generation and those of thermal energy. In addition, the costs of electricity will be estimated from coal consumption (Jakeman, 2006). The difference in the former and the later is the difference in costs of electricity generation between biogas production and coal consumption.

For the calculation of GHG emission reduction between biogas production and coal consumption with two elements will be analysed: the GHG emission in biogas project and those caused by coal consumption. Thus, the GHG emission in the biogas project is the difference between GHG emission from electricity generation and thermal energy production and from coal consumption (Johnson, 2007). In view of that, the GHG emission reduction between biogas production and coal consumption can be calculated.

The difference in costs of GHG emissions and GHG emission reduction is the GHG emission reduction costs between biogas project and coal consumption (Kemfert, 2006).

After the description of the procedure followed, the economic and ecological aspects of three biogas projects will be made concerning the methodologies already presented.

4 Economic and ecological aspects of biogas projects

In this chapter, the economic and ecological analysis of three biogas projects will be made. The first project is a household biogas project concerning thermal energy production and utilization. The other two biogas projects are meant for the generation of electricity for sale, for use by local companies as well as for use by medium and large scale farms. The biogas is also meant for generation of thermal energy utilization. This chapter will analyze and approach the subject from different angles with virous methodologies.

4.1 Economic and ecological aspects of household biogas project

This project is a household biogas project for economic and ecological analysis. The project is also the first CDM household biogas project in China. The economic analysis using various kinds of methodology will be made for thermal energy utilization. The GHG emissions and emission reduction will also be analysed.

4.1.1 Project background

Chinese Government reports indicate that biogas utilization for rural households is a means of improving living standards and addressing environmental degradation. China's biogas development has enjoyed strong governmental support in recent years. China has also had long time corporation with The World Bank in different areas, such as technology transfer, agriculture and industrial sectors, etc. The World Bank group offers loans, advice, and an array of customized resources to more than 100 developing countries for capital programs with a goal of reducing poverty (MOA, 2008). The bank has also been assigned temporary management responsibility for a clean technology fund which focuses on making renewable energy cost-effective utilizing coal-fired power. Thus, this project development objective is to deliver direct economic and ecological benefits from the integration of biogas in farming and cooking in rural households. Furthermore, this project also aims at GHG emission reduction through methane combustion and reduced burning of coal in project areas (MOA, 2008).

Under the above-mentioned coorporation between China and The World Bank, this Biogas Household Project was established between 2007 and 2008 in Hubei province in the Enshi administrative region with 33,000 households. The project proposed the construction of household biogas digester at the project site, which involved of eight countries and cities.

These counties and cities include Enshi city, Jianshi county, Lichuan city, Badong county, Xuan’en county, Xianfeng county, Laifeng county and Hefeng county.

These counties are located in poor mountainous areas in the southwest of Hubei province. Map 1 indicates the annual income in Hubei province of eight counties. The Enshi administrative region is a region in Hubei province with an annual income of less than 519.4 RMBin rural area which makes Enshi one of the poorest counties in Hubei province.

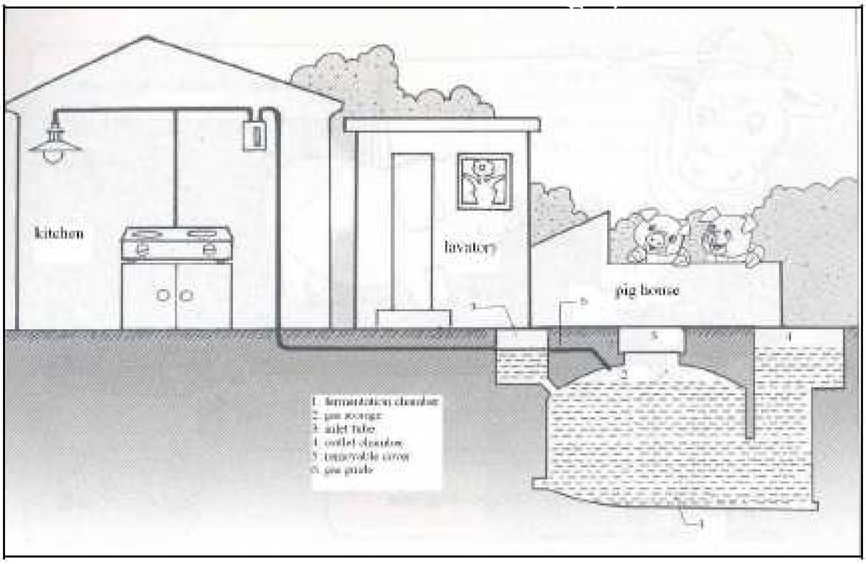
Map 1: The annual income in Hubei province

+ The annual income at the first level: up to 3589.4 ￥ (3 counties)
▨ The annual income at the second level between 692.5 ￥ and 865.6 ￥ (8 counties)
– The annual income at the third level between 519.4 ￥ and 692.5 ￥ (3 counties)
· The annual income at the fourth level under 519.4 ￥ (3 counties)

Source: Hubei Statistics Bureau, 2006

The project activities would be carried out in eight counties/cities including Enshi, Lichuan, Jianshi, Badong, Xuan’en, Xianfeng, Laifeng and Hefeng. Each county/city has many towns and villages with differently sized biogas digesters to be installed (see Map 3 and Table 8). The whole project plan involves constructing 10,082 biogas digesters with a reactor size of 8 m^3, 14,181 with 10 m^3; 4,167 with 12 m^3 and 4,570 with the 15 m^3 under the biogas technology “one household one tank” system (see Chapter 2.1) depending on the numbers of people and the livestock population per household (see Map 2). Moreover, the project will be estimated for a household based biogas CDM implementation, as a result of the changing of traditional manure management system and resulting methane emission reduction for the households' thermal energy needs, as well as by replacing fossil fuel such as coal, which the farmers made use of earlier on.

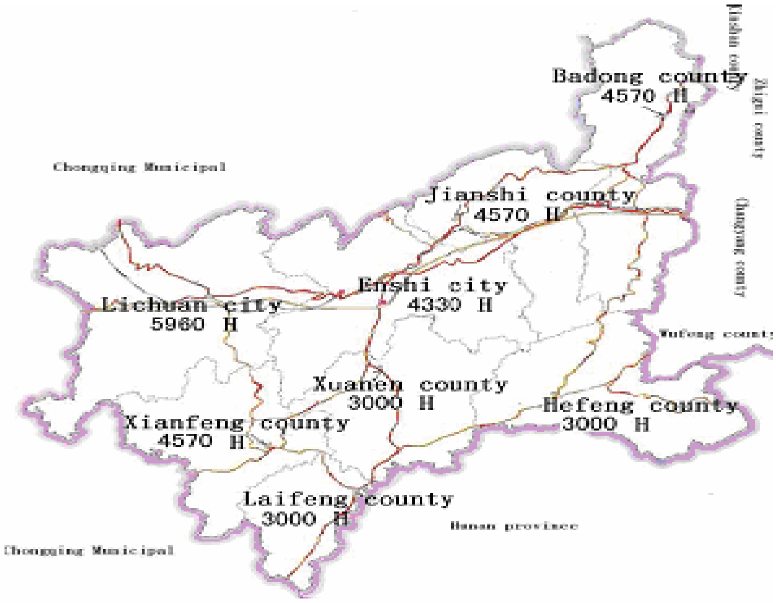
Map 2: Biogas project with "one household one tank" system



Source: UNFCCC, 2008

All construction installation is expected to be completed by the end of the year 2008. Map 3 and Table 8 indicate the activity location in each county and the installation of biogas digester depending on township numbers (see Table 8).

Map 3: Project Area



Source: UNFCCC, 2008

Each of county/city has between 3 to 15 townships, the total number of townships being 81 in the project site. Each of the townships has different number of villages ranging from 17 to 122. Depending on the farm household size and the swine population in each of farm, 3,000 to 5,960 household biogas digester could be installed considering the total of 33,000 biogas digesters available. Due to the household family situation, the biogas digester size for each family could be either 8 m^3, 10 m^3, 12 m^3 or 15 m^3. Table 8 indicates the project information.

Table 8: Project information

County/ City	№ of township	№ of villages	№ of biogas installations	Average № of swin/household	№ of biogas digesters			
					8 m^3	10 m^3	12m^3	15m^3
Enshi	15	47	4,330	4.7	1,918	2,412		
Jianshi	10	81	4,570	4.3	540	4,030		
Badong	12	75	4,570	4.6	1,581	2,989		
Lichuan	14	122	5,960	4.6	3,043	2,917		
Xuan’en	9	91	3,000	5.0		1,833	1,167	
Xianfeng	10	17	4,570	5.6				4,570
Laifeng	8	119	3,000	4.2	3,000			
Hefeng	3	73	3,000	4.6			3,000	
Total	81	625	33,000	4.7	10,082	14,181	4,167	4,570

Source: UNFCCC, 2008

As can be seen in Table 8, after research planning and discussion with the family, there are more or less varying numbers of biogas installations for these eight counties and cities. In addition, the average number of swine for each household is estimated to be between 4.3 and 5.0. Moreover, different numbers of biogas digesters ranging from 1,167 to 4,570 are planned.

According to the project activity, the 33,000 biogas digesters will be installed based on individual sizes for each selected household with The World Bank. The World Bank loan has covered US$ 4.34 million (32.98 million RMB). Government funding has also amounted to US$ 2.34 million (17.78 million RMB) and the rest, US$ 10.22 million (77.67 million RMB) are required from the participating farmers’. The total investment costs have amounted to US$ 16.99 million (129.12 million RMB). This includes biogas digester installation, operation and maintenance costs. The World Bank contribution in the form of a loan amounts to 25.55% of the total investment cost. Government funding covered 14.28% and the remaining 60.17% must be paid by farmers’. The cost situation is indicated in Table 9.

Table 9: Cost situation of household biogas digester

Biogas digester volume	8 m^3	10 m^3	12 m^3	15 m^3
Average cost, RMB	3,085	3,410	3,620	3,970
The World Bank loan and government counterpart fund, RMB	1,000	1,000	1,000	1,000
Farmen contribution, RMB	2,085	2,410	2,620	2,970

Source: MOA,2006
Note: $US= 7.6RMB

On average, each biogas digester for household utilization ranges between US$ 406 (3,085 RMB) and US$ 576 (3,970 RMB). This also depends on the size of the digesters which, in this context, ranges from 8 m^3 to 15 m^3. Moreover, the farmers can obtain from The World Bank and the Chinese government 1,000 RMB for each biogas digester. This means that the participating farmers need to pay between 2,085 RMB and 2,970 RMB themselves and also need to mobilize the maintenance costs during the lifetime of biogas digester utilization. Thus, the investment costs include all expenses which include excavation-work and plant construction (biogas digester, gas-holder. the pipeline system, gas utilization, the storage system and other buildings). Moreover, the regions could also propose larger scale plants which could be more economical for the biogas digester construction, but the costs of laying pipes could be decreased by “economics term” and the livestock and human waste are hard to be collected and transported. Thus, the economic analyses will be presented in Chapter 4.1.2.

4.1.2 Economic analyses

This section concerns the economic and ecological analyses for this selected household biogas project. There are two parts in this chapter, the first is economic analysis. In this part, the economic analysis concerning cost-revenue analysis will be made of farmers’ share in the investment costs and of total investment. Other economic analyses concerning methodologies will also be made..

4.1.2.1 Cost-revenue analyses

The cost- revenue analyses will be made involving two parts: first concerning farmers’ investment costs; the second- relating to total invesement costs.

- Cost-revenue analysis from farmers investment costs

Thus, the total investment costs required from farmers are estimated to be 2,085 RMB for 8 m^3, digester; 2,410 RMB for 10 m^3, 2,620 RMB for 12 m^3 and 2,970 RMB for 15 m^3 (see

Table 9), which include biogas digester and biogas stove costs. From the experience of China, waste from three to four herd of swine are enough for substrates for 8 m^3 digester biogas production. Moreover, an example shows that the 8 m^3 household biogas digester's investment costs are 3,077 RMB. The equipment has a lifespan of up to 20 years. The operation and maintenance costs must be considered as 120 RMB annually (MOA, 2000), and the insurance should also be calculated. After biogas digester construction, for the initial stage digester operation about 100 RMB for substrates costs are to be considered. In order to keep normal operation of the biogas digester, the organic material should be totally changed every three to four years. In this context, 100 RMB must be paid as substrate purchase every three or four years. There can also be some room given for unforeseen contingency plans. This plan should also be instituted in anticipation of rising costs (China newenergy information, 2007) for the annual imputed costs calculation. The following costs should be considered:

- ✓ The interest charges
- ✓ The amortization costs
- ✓ The costs of repair
- ✓ The costs of insurance
- ✓ The substrate costs
- ✓ Any other costs

For this calculation, all the above-mentioned default numbers can be referred to for calculation. As the original data shows, each of the household biogas costs amounted to 2,085 RMB, 2,410 RMB, 2,620 RMB and 2,970 RMB. The interest rate can be taken as 5.76% for the Bank of China taking into the account the long term deposit interest rate. Moreover, the amortization costs can be taken as an equipment lifetime of 20 years, including regular maintenance and repair. Some parts of the plant have to be replaced at some time between 8 to 10 years. As from the 8 m^3 biogas digester experience the repair factor can be taken as 3.9% of investment costs (MOA, 2000). In addition, here it should also be mentioned that the steel gas holder need to be repaired every year or every second year. Apart from that, the factor of insurance costs accounts for 0.5% of the total costs as it is usual for biogas plants. Moreover, although the substrate costs in this project can be regarded as "free of charge" (Chen, 1997), but considering the changes in substrates every three to four years, these costs must be calculated with re-discounted costs for substrates purchase of 100 RMB for a 8 m^3 biogas digester for first time acquisition and then repeatedly every three to four years. Thus, the costs of substrates purchase for a 10 m^3, a 12 m^3 and a 15 m^3 can be calculated to be 125 RMB, 150 RMB and 190 RMB. Furthermore, the other costs might be explained as 2% of the total investment costs. This part of costs can be calculated as some unforeseen costs in the biogas digester operation. In this project the workers' wages can be ignored, because the proposed biogas plants are on a small scale and about one or two people from each of family can complete the work for normal operations. In this context, they may only be required to change the substrate every of three or four years. The annual imputed costs can be illustrated as following Table 10.

Table 10: The annual biogas digesters project imputed costs from farmers investment share

Components, RMB/a	Value			
	8 m^3	10 m^3	12 m^3	15 m^3
Interest charges① 5.76% of investment costs 61.9% of factor of capital commitment	74	86	93	106
Amortization 20 years of lifetime	104	121	131	149
Costs of repair ② 3.9% of total investment costs	120	133	141	155
Costs of insurance 0.5% of investment costs	15	17	18	20
Substrate costs③	36	45	54	68
Other costs ④ 2% of investment costs from farmers' share	42	48	52	59
Total annual imputed costs of each household size	393	450	490	556
Total annual imputed costs of household sizes⑤	3,953,906	6,379,305	2,043,132	2,542,044
Total annual imputed costs from project activity of farmers investment share	14,918,388			

Notes:

The average costs of each biogas digester are 2,085, 2,410, 2,626 and 2,970 RMB *concerning the digester size of 8* m^3*, 1 0*m^3*, 12* m^3 *and 15* m^3

① *The Bank of China's long time interest rate for deposit iss taken 5.76%.*

② *For 8*m^3 *biogas digester operation, the annual costs of repair can be taken 120 RMB, as the average of investment costs for a 8* m^3 *digester, the costs of repair rate can be considered as 3.9%.*

③*The distributed substrate costs should be calculated from two parts, the 1st the substrates should be changed for every three years to keep biogas production; the 2nd the first time substrate must be paid on average an amount of 100 RMB as the default number for a 8* m^3 *household biogas digester, so the calculation here can be as follows: 125 RMB, 150 RMB and 190 RMB required to be paid for the changing of substrates every three years and the first time substrate requirement of the digester at the start of operation, depending on the planned digester size for project activity of 10* m^3*, 12* m^3*, 15* m^3

④ *Other costs comprise 2% of investment costs, denoting unforeseen circumstances*

⑤ *There are 10,082 units biogas digesters with 8* m^3*, 14,181 units with 10* m^3*; 4167 units with 12* m^3 *and 4570 units with 15* m^3

With the supported investments costs for different sizes of biogas digesters, the costs of repair are the largest part among other components of costs of the project. In this project region, knowledge of biogas technology is lacking. Moreover, in absence of digester maintenance, it may happen that the plant lasts long for normal operations. Next, the amortization costs are also large, which should also not be overlooked during the 20 years stipulated. In addition, the interest charges, other unforessen costs and insurance costs must also be taken into account for the project, as well as substrate costs. Although the substrates costs are smaller compared with others in the project, however, the initial substrate selection must be done once the biogas digester begins to operate. It should also be noted that the initial costs incurred have to be paid every three years, taking in to account the re-discounted costs. Thus, total annual imputed costs of each household size and annual imputed costs are estimated. The annual imputed costs of the entire project activity of farmers investment share are 14.92 million RMB.

After annual costs calculation, the revenue must also interest farmers as stakeholders in the project. The revenue in this project can be calculated as the revenue from substituted fossil energy which farmers utilize in absence of biogas digester operation for household thermal energy requirements, such as cooking, lighting and heating. For the Chinese agricultural farmers normally coal, firewood and straw can be utilized as source of energy production. Due to this project area’s high attitude and limited living standard, coal is the main energy source used for heat. In this context, the revenue can be made for substituting the coal by biogas.

Animal waste produce biogas. In this context, the biogas production must be calculated. The annual average waste production of swine in rural China can be considered as 1,825 kg, and the default number for biogas production from kilogram swine waste can be taken as 0.35 m^3, the dry matter of swine waste share accounts 18% usually. There are between 4.2 and 5.6 average number of swine population in each city and county of project activity in Enshi administrative region, with the number of household biogas installation between 3,000 to 5,960 units of the total (see Table 8), and thus the total annual biogas production for this region can be calculated (see Table 8). The Table 11 and 12 show detailed information of the default number of annual swine waste production, biogas production, swine waste dry matter and calculated biogas production.

Table 11: Default number for biogas production from swine waste calculation

	Unit	Amount
Annual swine waste production	kg FM/a	1,825
Biogas production rate from swine waste	m^3/kg TM	0.35
Dry matter of swine waste from swine waste	TM/kgFM	0.18
Biogas production from swine waste	m^3/a	115

Source: MOA, 2006b

The biogas production in project site is indicated in Table 12.

Table 12: Biogas production in eight cities and counties in Enshi administrative region

Project activity counties and cities in Enshi	Average of swine units in households	Number of households/ biogas digester	Biogas production m^3/a
Enshi	4.7	4,330	2,339,856
Jianshi	4.3	4,570	2,259,374
Badong	4.6	4,570	2,417,004
Lichuan	4.4	5,960	3,015,104
Xuan'en	5.0	3,000	1,724,625
Xianfeng	5.6	4,570	2,942,440
Laifeng	4.2	3,000	1,448,685
Hefeng	4.6	3,000	1,586,655
Total	4.7	33,000	17,733,744

Source: MOA, 2006b

In Table 11 and 12, the biogas production accounts for 115 m^3 annually based on defaulted number from the literature of annual swine waste production, biogas production rate and dry matter rate in China's rural areas. Considering the average of swine units in each household and the proposed number of biogas digesters from eight counties and cities in Enshi administrative region, total biogas production can be calculated to be as 17.73 million m^3 annually. This amount of biogas can be used as the source of thermal energy for household utilization, so that the thermal energy can be calculated from total amount of biogas production. In the absence of biogas utilization, the primary energy here can be regarded as coal. In order to produce the same amount of thermal energy from coal consumption, household from these eight areas of project activity must consume large amount of coal. In this regard, the energy production from biogas and energy consumption from coal will be considered as the same value[9]. Table 13 explains the coal consumption for the total thermal energy production as the same amount as from biogas.

---

[9] In this context, the energy production from biogas can be considered the same value as that of energy consumption under other equal conditions.

Table 13: Required coal consumption

Biogas		
	Unit	Value
Total production	m^3/a	17,733,744
Thermal value	MJ/m^3	20
Thermal value①	kWh_{th}/m^3	5.56
Total thermal value	kWh_{th}/a	**98,520,800**

Coal consumption		
	Unit	Value
Total thermal value	kWh_{th}/a	**98,520,800**
Thermal value	MJ/kg	15.20
Thermal value②	kWh_{th}/kg	4.22
Total consumption	kg/a	23,318,694

Note:

①*The coversion between MJ and kWh is equal to 0.278. Thus, the thermal value of biogas is equal to 20MJ/m^3, or 5.56 kWh/m^3*

② *Thermal value from the coal content is equal to 4.22 kWh_{th}/kg for this project*

It is very clear from Table 13 that with the same amount of thermal energy production from biogas, the total thermal value from coal is also accounted for 98.52 kWh/a. The thermal value for coal is 15.20 MJ per kilogram, and is 4.22 kWh per kilogram for coal consumption. Thus, the total amount 23.32 million kilogram coal can be substituted with the consumption of biogas annually . It should be noted that the costs of different equipment are considered.

Next, the costs for total energy production from biogas and from coal consumption will be evaluated. First, from biogas production, with the total imputed biogas costs (see Table 10) and total biogas production (see Table 13), the costs of biogas per cubic meter can be calculated. Thus, with the annual value of thermal generated from biogas, the thermal energy costs could also be estimated per kilowatt hour.

With the total coal consumption (see Table 13) and the costs of coal consumption per kilogram, the costs for total energy concumption can be estimated. Here, the price of coal is considered to be 680 RMB per ton. In reality, the price can fluctuate between 335 RMB and 790 RMB in the market for this region. Thus, with the same amount of thermal energy from coal consumption like that from biogas utilization and total costs of coal stoves, the costs for thermal energy consumption from coal can be calculated. Table 14 illustrates the costs of biogas production and coal consumption with the same value of thermal energy production.

Table 14: Costs for total energy production from biogas and from coal consumption

Biogas		
	Unit	Value
Total costs	million RMB/a	14.92
Total Production	million m^3/a	17.73
Costs	RMB/m^3	0.84
Total energy production	million kWh_{th}/a	98.52
Costs for thermal energy production	RMB/kWh_{th}	**0.151**

Coal		
	Unit	Value
Total energy production	million kWh_{th}/a	98.52
Total consumption	million kg/a	23.32
Cost	RMB/kg	0.68
Costs for total energy consumption	million RMB/a	**15.80**
Coal stove	million RMB	**0.28**
Costs for thermal energy consumption	RMB/kWh_{th}	**0.163**

Table 14 shows that the farmers pay fewer costs for thermal energy consumption from biogas production. Although the costs for thermal energy production from biogas and coal has been considered, the ecological and health benefits should not be neglected. The ecological aspect can be clarified that once biogas digester starts to operate, the farmer can utilize the thermal energy from biogas to substitute large amount of coal in this project activity, as biogas is a clean energy. The health benefits are from improved sanitation and hygienic conditions and can be derived from reduced indoor air pollution. It is to be noted that in rural China, the indoor air pollution exposure from the primary energy and some biomass (straw, firewood), is considered a hazardous pollutant. Moreover, the biogas fertilizer can be used and substituted by chemical fertilizer. This also provides environmental benefits. With the experience of China in rural biogas digester utilization, the users can demonstrate the significant health benefits compared to the non-users. In addition, the project represents the first household biogas digester CDM project in China. Income from the CDM can also help farmers to overcome such financial barriers.

Household biogas digester can also offer social benefits, the farmers learned about clean energy. Women might well have benefitted by reducing the time and energy spend on collecting firewood for cooking. Furthermore, due to the clean energy utilization, the improved quality of life are more important than any income or economic benefit.

After the total costs and revenue calculation with the farmers' share of investment, it is also interesting for the farmers in terms of the revenue obtained, as well as that for biogas production, thermal energy consumption and coal savings for each of household biogas digester. The detailed calculation is indicated in Table 15.

Table 15: Annual biogas production, thermal value and coal saving in household digester size of $8m^3$, $10m^3$, $12m^3$ and $15m^3$

Digester size, m^3	Biogas production①, m^3/a	Thermal value, kWh/a	Coal savings, kg/a
8	416	2,313	548
10	520	2,891	685
12	624	3,469	822
15	780	4,337	1,028

Note:

① *Biogas production is equal that of each of cubic meter digester multiplied by digester size. In this context, the biogas production of each of cubit meter is equal to relation of total biogas production and total digester units (relating to Tables 8 and 12).*

In Table 15, the total household digester units representing household digester numbers is presented. The annual thermal energy production and coal saving can also be calculated.

Thus, the biogas production, thermal energy value and coal consumption by eight counties and cities can be also estimated. The result is shown in Annex I-1.

After cost-revenue analysis from farmers' investment share, the project's costs and revenue are also important for investors. Thus, the costs and revenue with total investment costs will be analysed.

- Cost-revenue analysis with total investment costs

Like shown in Table 9, the total investment costs are calculated to be 3,085 RMB and 3,410 RMB for digester sizes of 8 m^3 and 10 m^3. The total investment costs are also 3,620 RMB and 3,970 RMB for digester sizes of 12 m^3 and 15 m^3. In terms of this, The World Bank and the Chinese Government's Counterpart Funding part pay 1,000 RMB for each of household biogas digester, another part is the farmers investment share. The procedure for the calculations is similar to that of costs evaluation of the farmers' investment share. It is in this regard that The World Bank offered a 6% bank loan for the project which is 11% lower than the loan on the market. Concerning the bank loan interest rate of between 6% and 5.76% from the Bank of China's long-term deposit interest rate, the interest charges can be calculated from 6% of The World Bank share, 5.76% of Chinese government funding and from the investment share from farmers. For the amortization costs, the lifetime of the equipments can be regarded as 20 years. Apart from that, the repair factor here would be considered as 3.9%, the insurance costs might be also computed as 0.5% of the total investment costs. Here the substrate costs are separated into two parts for calculation purposes: the first time substrate costs and every three or four years the total substrates change costs.

Thus, the costs components can be made to follow the same procedure as for the calculation from farmers' total investment share (see Table 10), only the interest charges and amortization costs must be different concerning the different interest rate and investment costs. The detailed calculation of annual imputed costs for total investment costs can be showed in Table 16.

Table 16: The annual biogas digesters project imputed costs from project total investment

Components, RMB/a	Value			
	8 m^3	10 m^3	12 m^3	15 m^3
Interest charges① 5.79% of investment costs	111	122	130	142
Amortization costs 20 years of lifetime	154	171	181	199
Costs of repair 3.9% of investment costs	120	133	141	155
Costs of insurance 0.5% of investment costs	15	17	18	20
Substrate costs	36	45	54	68
Other costs	61	68	72	79
Total annual imputed costs of each household size	498	556	5,967	663
Total annual imputed costs of household sizes	5,025,042	7,886,808	2,486,270	3,028,343
Total annual imputed costs from project activity of farmers investment share	18,426,463			

Notes:
The average costs of each biogas digester with digester size of 8 m^3, 10 m^3, 12 m^3 and 15 m^3 could be taken as 3,085 RMB, 3,410 RMB, 3,620 RMB and 3,970 RMB as individual investment costs
① *The Bank of China's long time interest rate for deposit is taken as 5.76%, The World Bank offered a loan of 6%, thus, the average interest charges rate can be calculated to be 5.79%, which could be calculated from The World Bank's share of 25.55% and from Counterpart Funding of 14.28% and from the farmers' share of 60.17%. The capital commitment factor has been taken to be 0.619*

The annual imputed costs are presented in Table 16. The procedure for calculation is similar to that of the annual costs estimation for farmers' share of investment. Thus, the different costs calculcation, between 5.03 million RMB to 3.03 million RMB, represented the total annual imputed costs per household size. Therefore, the total annual imputed costs from project activity of investment costs can be estimated to be 18.43 million RMB.

Costs calculation, the investment costs and that of all stakeholders (The World Bank, China Counterpart Funding and farmers) are taken into account. The annual total project revenue, annual project revenue for each county and city, as well as that for each of household must be calculated as the same value as is the case for farmers' investment costs. Moreover, the revenue for substituted coal consumption and biogas thermal energy production should be estimated as the same result to the project from farmer's investment share's calculation. Furthermore, considering the different estimated imputed costs from the farmer's investment share and from total investment, the value of costs for kilowatt hour of thermal value and that of biogas production and coal consumption should also be different. Thus, Table 17 is shown the costs for total energy production from biogas production and coal consumption.

Table 17: Costs for total energy production from project biogas production and from coal consumption

Biogas		
	Unit	Value
Total costs	million RMB/a	18.43
Total Production	million m^3/a	17.73
Cost	RMB/m^3	1.04
Total energy production	million kWh$_{th}$/a	98.52
Costs for total energy production	RMB/a	**0.187**

Coal		
	Unit	Value
Total energy production	million kWh$_{th}$/a	98.52
Total consumption	million kg/a	23.32
Cost	RMB/kg	0.68
Costs for total coal consumption	million RMB/a	15.80
Coal stove	million RMB	0.28
Costs for thermal energy consumption	RMB/kWh$_{th}$	0.163

Table 17 shows that the procedure for calculation of biogas production is the same as that of the farmers' share of investment (see Table 14). Here, the different result of costs for total energy production is due to the difference in total annual costs for biogas production. Thus, the biogas production costs per cubic meter is 1.04 RMB and the costs for total thermal energy production of total biogas are estimated to be 0.187 RMB per kilowatt hour. The costs for kilowatt hour thermal energy of coal consumption stayed the same as that for farmer's investment share, which are computed as 0.163 RMB(see Table 17).

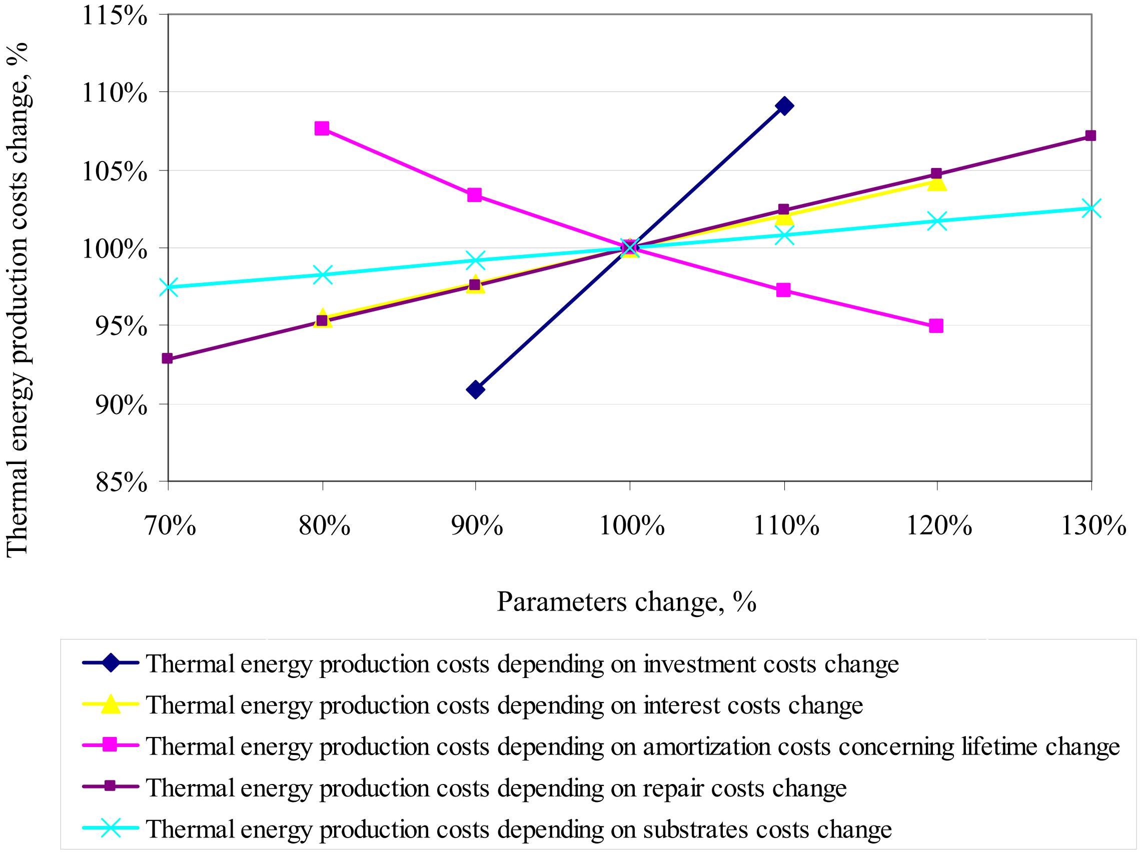
Thus, the cost-revnue for two scenarios has analysed. Actually, for the project owner, it will also be important to know which factors in the projects are more sensitive. In the next chapter (Chapter 4.1.2.2) a sensitivity analysis will be made for the project.

4.1.2.2 Sensitivity analysis

After project costs and revenue have already calculated, there is the need to carry out a sensitivity analysis. The annual total imputed costs were calculated as 18.43 million RMB (see Table 17). That for thermal energy was also calculated as 98.52 million kWh (see Table 17), while that for thermal costs were also estimated to be 0.187 RMB/kWh.

Actually, each factor in the cost-calculation system has more or less an influence on the result, the largest costs parts for cost-calculation included, interest charges, amortization costs and costs of repair. Moreover, the substrates costs have also more feasibility to change. Thus, the sensitivity analysis will be made for one kilowatt thermal energy costs from the change of investment costs, interest charges, amortization costs, costs of repair, and substrates costs. In order to get the detailed calculation, first of all, the calculation must be done for one kilowatt hour thermal energy costs for each of household size, the result is presented in Annex I-2. Concerning the result from Annex I-2, the sensitivity analysis for thermal energy production costs depending on parameters change is presented in Figure 15.

Figure 15: Thermal energy production costs depending on parameters change



As can be ascertained from Figure 15, the the most sensitive factor is the parameter of investment costs with the change of +/-10%. The next most sensitive factor is amortization costs. The amortization costs parameter can be planned with the change of +/-10% and +/-20%. The third sensitive parameter is also the interest charges with the change of +/-10% and +/-20%. Moreover, the repair costs changefor this arranged project are between +/-10% and +/-30% considering the reference scenario. In addition, although the substrates costs parameter can be one of the most sensitive factors in the project as shown in Table 23, but the farmers as biogas digester users with a total of 33,000 households must arrange the substrates for the first time digester operation and also change the substrate every three or four years. This parameter change is planned between +/-10% to +/-30%.

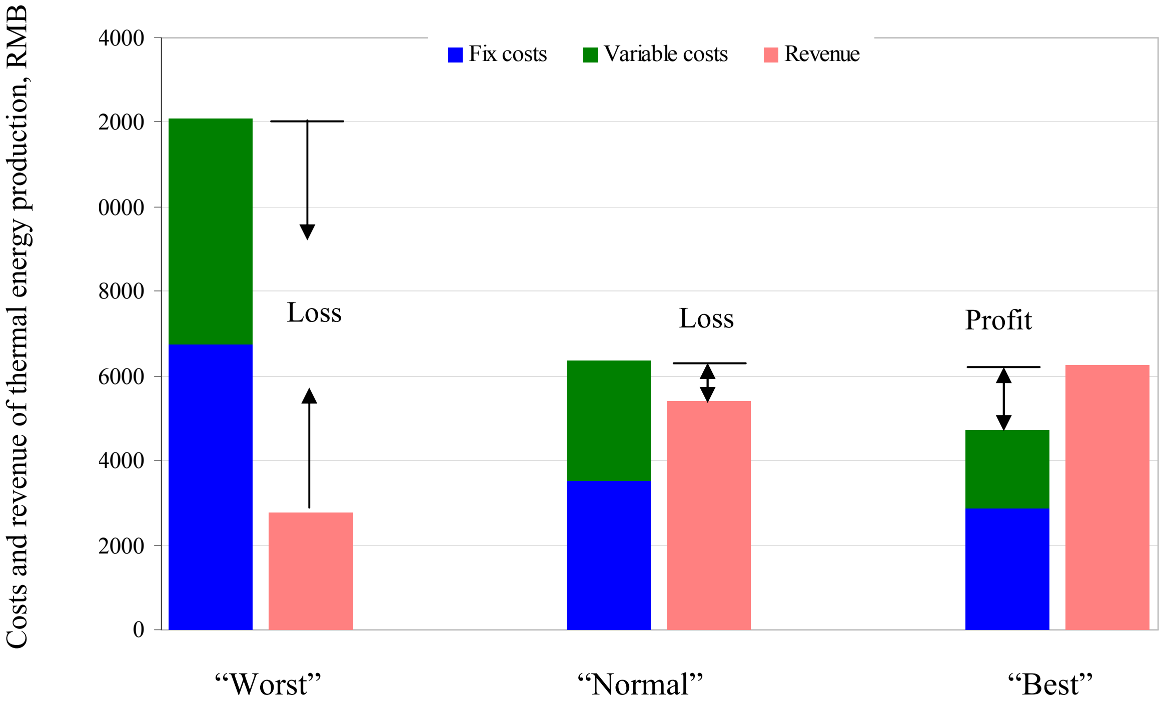
After sensitivity analysis, the other economic estimation could also be made with the “Worst”, the “Normal” and the “Best” cases.

4.1.2.3 The "Worst", "normal" and "best" cases

As indicated earlier, there are 33,000 households. These households plan to construct biogas household digester of different sizes ranging from 8 m^3, 10 m^3, 12 m^3 to 15 m^3 and according 10,082, 14,181, 4,167 and 4,570 units of each digester size. These numerous data could result in different annual costs, revenue and profit. That is the reason for the "Worst", the most "Normal" and the "Best" cases as the worst situation, the reference scenario and best situation for economic analysis is required to be estimated. From the annual costs part, the interest rate with respect to the reference Scenario is 5.79% of investment costs. The World Bank's share in terms of support is 6% and the long-term deposit interest of 5.76% is for Chinese Counterpart Funding and farmers own funds for investment; but the long-term deposit interest could fluctuate. So for the project operation, the interest rate on deposits can be estimated to be +/-20% for the best and worst situation. The lifetime of equipment is proposed to be around 20 years, just as the is thr case for the sensitivity analysis. This can be fluctuated by +/-20% of it as compared with the reference scenario. Considering the fact that the project is located in a remote area and the farmers have an average level of education coupled with the lack of technological knowledge, the costs of repair can be higher than in the reference scenario and after the training program, the costs of repair can also be expected to be reduced. In this context, the costs of repair are estimated to be +/-20% compared with the reference scenario. The insurance charges are planed as +/-10% of total investment costs due to it possible stability compared to other factors influencing the project. Then the substrate costs are variable and up to +/-30% of the investment costs.

Thus, the fix costs here include interest, amortization and insurance costs; the variable costs include repair, substrate and other costs. The revenue is calculated for thermal energy production based on the price of coal saved. Due to the possibility of different amount of biogas production and the possibility of different prices for thermal energy, the total revenue can be also be different. Figure 16 indicated the result of project "Worst", "Normal" and "Best" cases referring the results in Annex I-3.

Figure 16: The “Worst”, “Normal” and “Best” cases in project activity



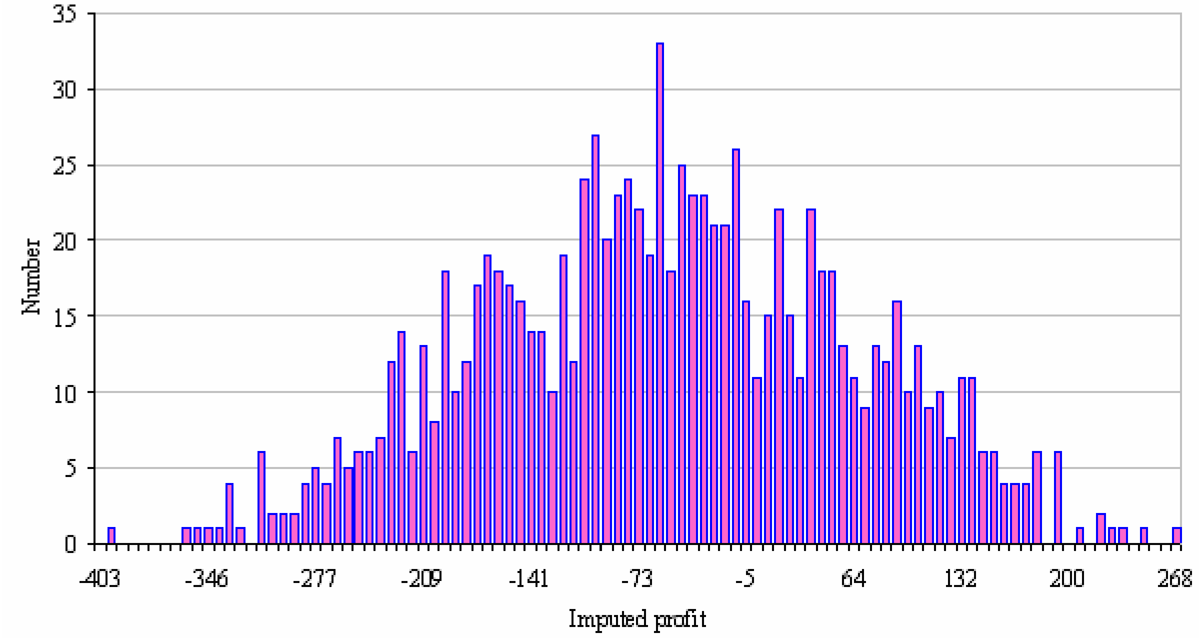
In Figure 16, in the “worst”, “normal” and “best” cases, the costs have involved the fixed costs and variable costs of thermal energy production for total project. Thus, the “worst” case costs of thermal energy production is 12,000 RMB per kilowatt hour with the revenue of thermal energy production slightly lower than 3,000 RMB per kilowatt hour. The normal case situation is the reference scenario which, unfortunately, the revenue is also less than the costs of thermal energy production. Due to the lower costs of coal consumption and coal stove, the farmers of project activity before had only low costs for thermal energy consumption. As a result, the total costs and revenue for thermal energy production which include different household digester sizes are computed to be 6,100 RMB and 5,300 RMB. The Best case indicated that the total costs of thermal energy production are 5,000 RMB, and 5,969 RMBfor as revenue.

The “worst”, “normal” and “best” cases analyses have been completed for this project. Moreover, the project risk may also be interesting for project ower. Thus, the next part will make project risk analysis employing the Monto-Carlo-Simulation.

4.1.2.4 Monte- Carlo- simulation risk analysis

The Monte- Carlo- simulation analysis must be carried out for each of 8 m^3, 10 m^3, 12 m^3 and 15m^3 biogas digesters. After programme installation, every factor for cost-revenue estimation will be estimated using the Monte-Carlo-Simulation (see Cahpter 3.1.6). Here, the Monte-Carlo-Simulation could be made for a 15 m^3 biogas digester as an example. The situation for other sizes of household digestrers is similar to that of a 15 m^3. Only the results for a 15 m^3 is slightly better than for the others. Thus, the density and distribution function for each of digesters with 15 m^3 are explained more in detail in the Figure 17 and 18.

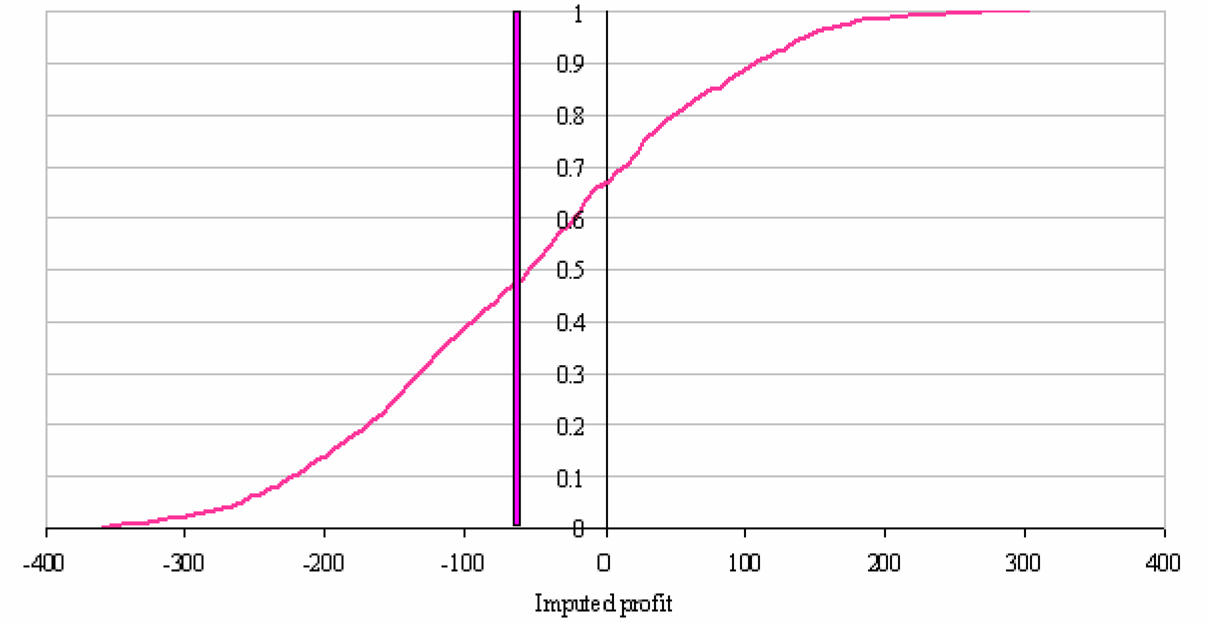
Figure 17: Density function from 15 m^3 biogas digester



Source: Own calculation based on the data from Rauh, 2008

In Figure 17, the profit would run between -480RMB and 280RMB, and the profit of about -60 RMB, which could be considered the best opportunity to obtain profit (see Annex 1). Thus, the distribution fuction for a 15 m^3 biogas digester is shown in Figure 18.

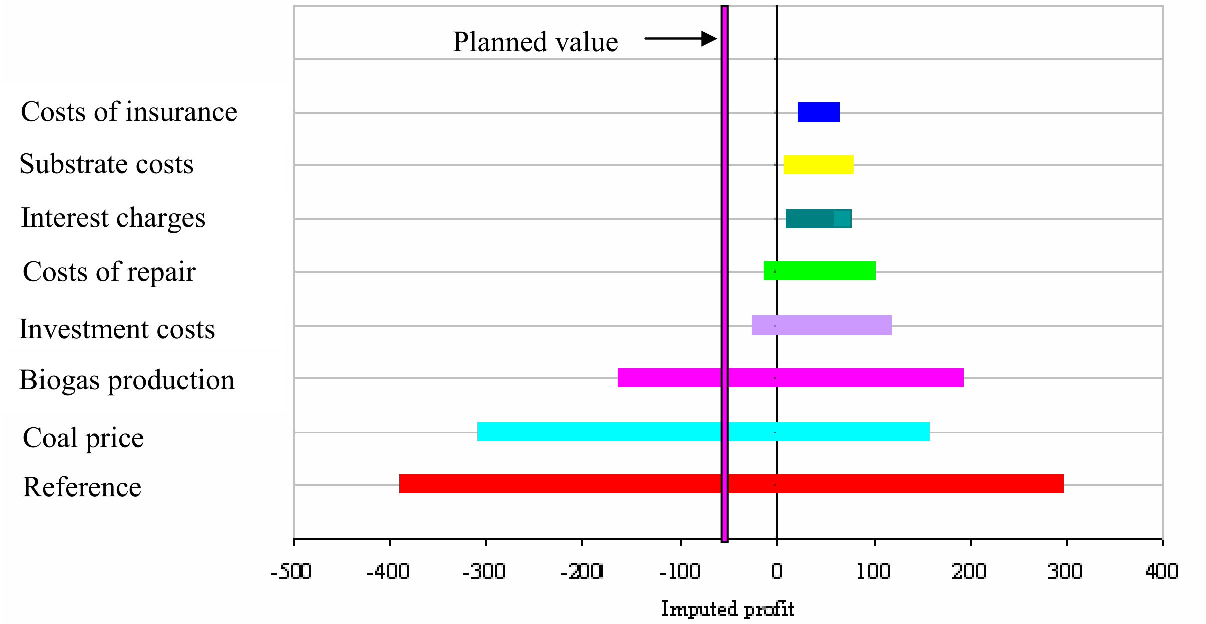
Figure 18: Distribution function from 15 m^3 biogas digester



Source: Own calculation based on the data from Rauh, 2008

As seen in Figure 18, the project introduces a distribution function. The chance to obtain profit is computed to be 33% for a 15 m^3 biogas digester. Its calculation based on the simulation is between -360 RMBand 300 RMB. The highest value is, however, estimated to be -60 RMB with the possibility of 52% (see Annex 1). Figure 19 shows the imputed profit band from biogas production, the coal price, investment costs, substrate costs, costs of repair and insurance for an example, a 15 m^3 biogas digester.

Figure 19: Imputed profit band for 15 m^{3}biogas digester

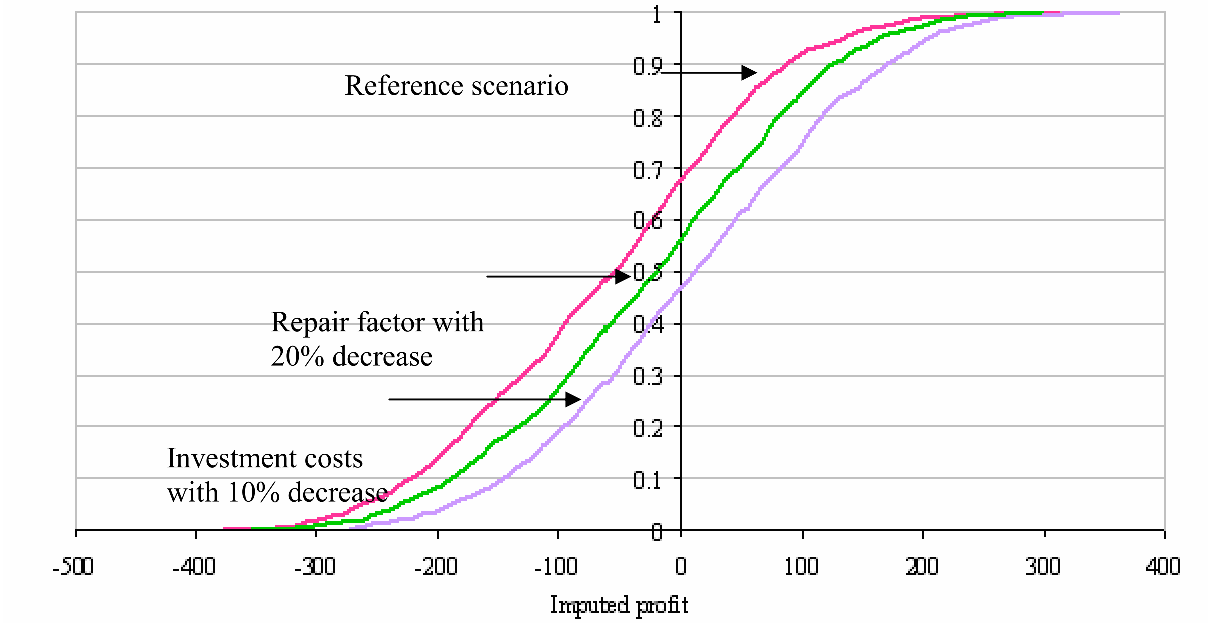


Source: Own calculation based on the data from Rauh, 2008

As can be seen in Figure 19, the factor of coal price and biogas production are most effective than any other factors. In this context, the other factors affect project's profit less. Concerning of the factor influence, the profit shows absolute positive result, when interest charges and substrate costs change, as well as the factor of costs of insurance. Moreover, the pink vertical line denotes planned value, which run though the imputed profit band (see Annex 1). Beside the density function and imputed profit band explanation, the imputed profit can also be illustrated with distribution function depending on the above-mentioned factors.

Monte-Carlo-Simulation can also be made with a distribution function for changing results concerning the factor's variation. After running the programme for each of the factors in cost-revenue analysis, taken an example as household digester with a size of 15 m^3, the effect of essential parameters in imputed profit can be made from the factor change of costs of repair factor with -20% and investment costs with -10%. The programme running result can be illustrated for each of the household biogas digester in Figure 20.

Figure 20: Effect of essential parameters in imputed profit for biogas digester with 15 m^3



Source: Own calculation based on the data from Rauh, 2008

The costs of repair, investment costs change made in Figures 20, if repair factor had been reduced by 20%, the profit for 15 m^3 biogas digester could have been estimated to be about 15%. If the investment costs were reduced by 10% , the possibility of accruing profit could have been considered to be 15% for this size of biogas digester (see Annex 1).

Thus, the economic analyses are completed for the project. In addition, as the first CDM project in China, this project also offers ecoligcal benefits. So, the next section in chis chapter will present the ecological analyses for this selected household biogas project.

4.1.3 Ecological analyses

This is the first CDM household project in China. As indicated in the methodology, the investment, technological and Barrier due to prevailing practice or others need detailed explanation. Considering the invesement, farmers obtain financial support from outside. However, farmers from individual households have to pay 60% of funding themselves out of their share of investment. According to the project design information from 4.1.1, the annual average income in rural Enshi administrative region in Hubei province is under 520 RMB per household in 2006 year. In addition, households will continue to pay for operating, maintenance and substrates costs during the biogas digesters operating lifetime. Thus, many household would end up with a significant financial gap. In this context, the project could not be completed as planned (MOA, 2006a).

The investment barriers need to be considered by households, in addition to that of technical constraints. The project offers new technology with the waste management system. The project located in such a remote area, means that most farmers lack of technical knowledge. That is the key reason why there will be the need to increase know-how in the area of biogas digester operation and management (MOA, 2008).

Barriers from prevailing practice for the project can be considered as follows. The lack of regulation of better manure management system and better cooking methods in this area are some bottlenecks envisaged in addition to the large amount share for individual households. Hubei province began to demonstrate the applicability of biogas digester to improve the standars of living of farmers, but due to the limited support in term of finance, the biogas digester installations development was gradual. The CDM project can be provided as an incentive for the biogas digester development, so that supported household have chance to improve their living conditions (IPCC, 2007c).

Thus, for the ecological analyses, the carbon dioxide emissions will be made. The costs of emission reudction from project activity and that for entire project will also be estimated. In addition, financial situation for CDM project will be also analysed.

4.1.3.1 Carbon dioxide emission analysis

According to the CDM methodology for Methane recovery in agricultural activities at household/small farm level, this project CDM will be done as considering the follows steps: the first, identification of barrier analysis; the second, CO_2 emission reduction for the project and the last, CO_2 emission reduction costs for the whole project.

With the reference to the methodology described, the GHG emission reduction is the difference between the baseline emissions and project activity.

Baseline emissions Therefore, the total baseline emissios from households can be calculated as the sum of the baseline CH_4 emissions from manure management system and the baseline CO_2 emissions from coal consumption. The result of the baseline emissions for each of household are indicated in Table 18. The calculations are also presented in Annex I-5 and I-7.

Table 18: Baseline emissions

Conutry/city	Baseline emissions each of household digester① tCO_{2e}/a			
	8 m^3	10 m^3	12 m^3	15 m^3
Enshi	3.42	3.53		
Jianshi	3.42	3.53		
Badong	3.38	3.33		
Lichuan	3.31	3.41		
Xuan’en		3.48	3.64	
Xianfeng				3.91
Laifeng	3.12			
Hefeng			3.94	

Source: own calculation based on UNFCCC, 2008.

Note:
Baseline emissions = baseline methane emissions + baseline carbon dioxde emissions

In order to get the baseline emissions for the whole project involving 33,000 households, the numbers of household digesters must be considered (see Table 8). This should be multiplied by the Baseline emissions from each of the households. Thus, the total baseline emissions for the entire project are estimated to be 116,101 tons of CO_{2e} annually. The detailed calculation can be found in Annexes I-4, 5, 6, 7 and 8.

Project emissions The project emissions are seperated from methane emissions and carbon dioxide emissioins. Methane emissions are also from the biogas digesters while carbon dioxide emissions are from coal consumption. The result of project emissions for each of household is indicated in Table 19. In this context, the calculations are indicated in Annexes I-9, 10 and 11.

Table 19: Project emissions

Conutry/city	Project emissins for each of household digester, tCO_{2e}/a			
	8 m^3	10 m^3	12 m^3	15 m^3
Enshi	1.80	1.62		
Jianshi	1.83	1.75		
Badong	1.64	1.44		
Lichuan	1.87	1.74		
Xuan’en		1.73	1.70	
Xianfeng				1.88
Laifeng	1.41			
Hefeng			2.05	

The project emissions for each household are estimated to be between 1.41 tons and 1.88 tons annually. Thus, the total project emissions are estimated to be 57,163 tCO_{2e}/a. The detailed calculation can be found in Annex I-12.

Emission reduction After the calculations for BE_y and PE_y concerning both household individual digesters and the entire project, the ER_y can be obtained. The ER_y is actually the difference between BE_y and PE_y. Therefore, the ER_y for individual digester, as well as for the entire project can be calculated. Table 20 shows the ER_y by each household digester.

Table 20: Household emission reduction

	Household emission reduction, tCO_{2e}/a			
	8 m^3	10 m^3	12 m^3	15 m^3
Enshi	1.62	1.91		
Jianshi	1.59	1.77		
Badong	1.73	1.90		
Lichuan	1.44	1.67		
Xuan’en		1.75	1.94	
Xianfeng				2.03
Laifeng	1.72			
Hefeng			1.88	

Source: own calculation based on UNFCCC, 2008.

The numbers of ER_y for each of household digester are between 1.59 tCO_{2e}/a and 2.03 tCO_{2e}/a depending also on the household digester size. Thus, the ER_y for the entire project can also be calculated. Table 21 shows the result.

Table 21: Total project GHG emissions and emission reduction

	BE_y , tCO_{2e}/a	PE_y , tCO_{2e}/a	ER_y , tCO_{2e}/a
Value	116,101	57,163	58,938

Source: own calculation based on UNFCCC, 2008

The entire project ER_y is estimated to be 58,938 tons carbon dioxde annually. Moreover, it would be also interesting to present the emission reduction considering each digester size. Thus, due to the difference in the number of swine and coal consumption for each of county/city with the same digester size, the GHG emissions and emission reduction are also different. In this context, the average of emissions and emission reduction for each digester size will be calculated. Thus, Figure 21 illustrates the baseline, project emissions and emission reduction of thermal energy production from biogas for each of digester size.

Figure 21: Baseline emission, project emission and emission reduction for each of digester size of biogas thermal energy production

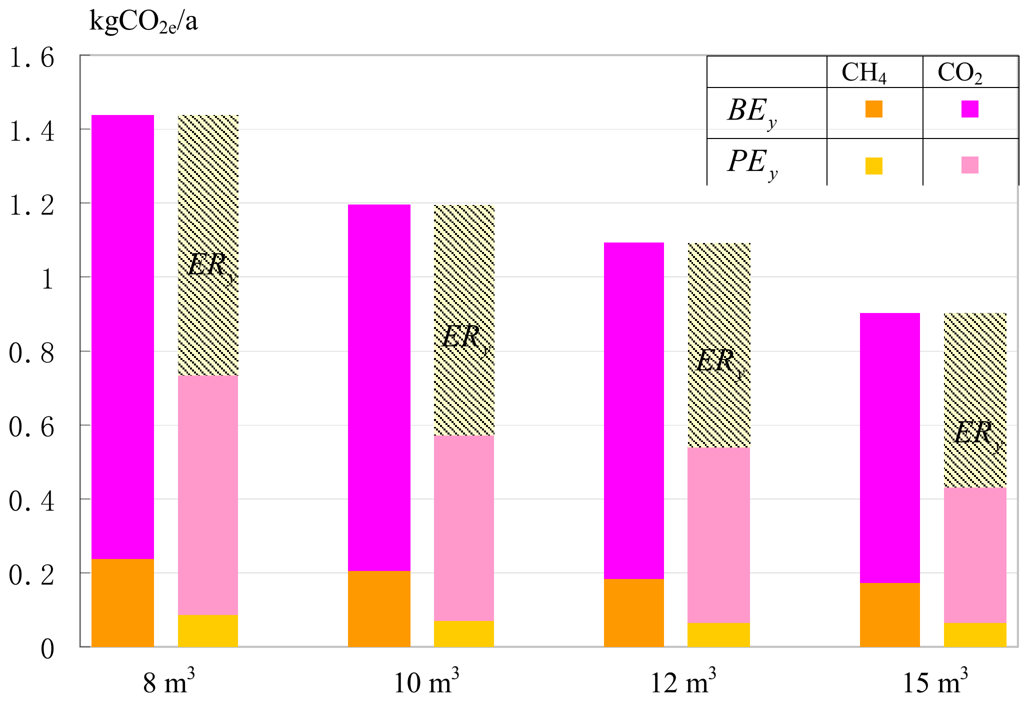


Figure 21 illustrates for the biogas thermal energy production how the digester size of 8 m^3 generates the greatest amount of GHG. The 8 m^3 digester also generated the largest amount of emission reduction compared with other digester sizes. The larger the size of the digester, the less GHG emission production and also the less emission reduction. The reason can be considered as the average of swine numbers, as well as also the number of household. Due to the individual household digester size, the numbers of swine can be very silimar for each household digester. However, the biogas production is different, concerning digester sizes.

In view of that, the thermal energy production is also different, concerning the biogas production.

After GHG emissions analysis for the entire biogas project and that of individual households, the next section will present the analysis of costs of the GHG emission reduction.

4.1.3.2 Costs of carbon dioxide emission reduction

- Costs of carbn dioxide emissions analysis for whole project

For the emission reduction costs analysis, the costs difference for thermal energy production between BE_y and PE_y must be considered, as well as emission reduction. Thus, for the costs difference, the total costs of thermal energy production for baseline GHG emissions can be regarded as the total costs of coal consumption, and it is computed as 32.55 million RMB (for the coal consumption costs see Table 13 and coal consumption before digesters installation see Annex I-6). The total costs of thermal energy production from project GHG emissions can be considered to be the sum of annual costs from biogas production and coal consumption after having installed the project are computed to be 35.56 million RMB (annual biogas production costs see Table 10 and the coal consumption costs see Table 13, as well as the coal consumption after digester construction see Annex I-9).

Moreover, the carbon emissions can consist of two types of emissions: the emission from BE_y and PE_y, which could be estimated to be 116.10 million kilogram GHG and 57.16 million kilogram GHG as total (see Table 21). As the result showed in Table 30, the ER_y can be considered as 58.94 million kilogram GHG annually. Table 23 shows the ER_y costs.

Table 22: CO_2 emission reduction costs for project activity based on traditional method of waste disposal

Thermal energy production total costs, million RMB		CO_2 emission production, million kg	
From baseline GHG emission	From Project GHG emission	From baseline GHG emission	From Project GHG emission
32.55	35.56	116.10	57.16
Difference 3.01		Difference -58.94	
Relation -0.051 RMB/kgCO_{2e}			

Thus, the difference between GHG emissions from the baseline and project scenarios are estimated to be 3.01 million RMB with the emission reduction of 58.94 million kilogram GHG. The emission reduction costs accounted for 0.051 RMB per kilogram of carbon dioxide emission liquidity, which amounted to US$ 6.8 per ton.

-Costs of carbn dioxide emission for project activity

The substituted biogas used for thermal energy production results also in GHG emission reduction. The emission reduction costs between thermal energy production from the project activity of biogas production and coal consumption is interesting to be presented. Thus, the thermal energy production costs for biogas production and for coal consumption are presented as mentioned above (see Table 16 and 17). Here, the emission reduction for both biogas production and coal consumption must also be estimated. Table 22 indicates the emission reduction costs.

Table 23: CO_2 emission reduction costs between thermal energy productions from project activity of biogas production and coal consumption

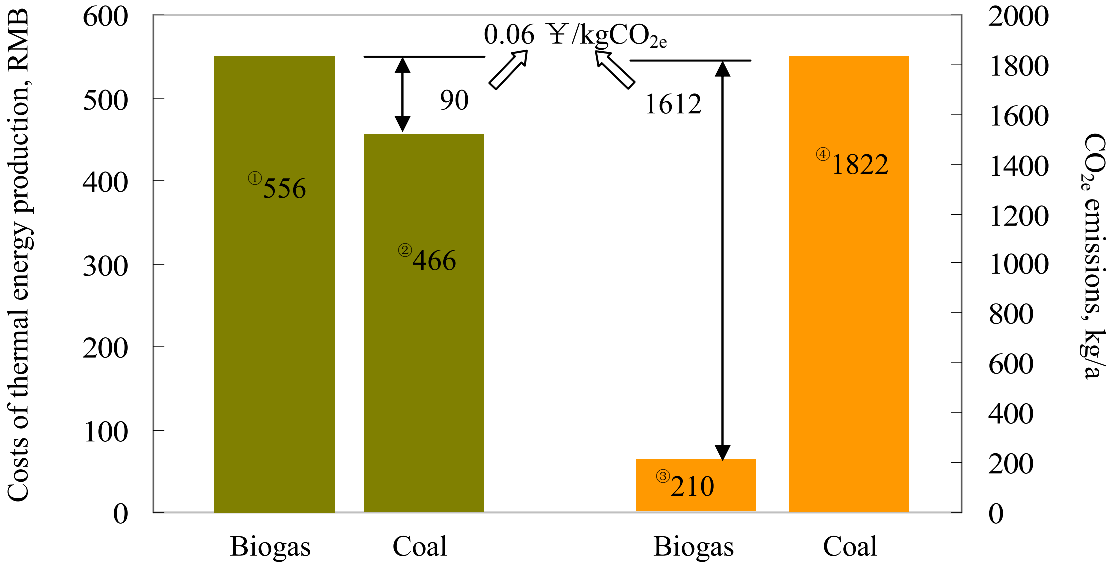
Thermal energy production total costs, million RMB		CO_{2e} emission production, million kg	
From total biogas production	From coal consumption	From total biogas production	From coal consumption
18.43	16.08	8.51	62.03
Difference 2.37		Difference -53.52	
Relation -0.044 RMB/kg			

In order to calculate the CO_2 emission reduction costs, some data must be taken from literature. Here, two references cited from the literature indicated that the household biogas digester with a size of $8m^3$ would have CO_2 emission production of 0.20 tons each year and the CO_2 emission production would be considered as 2.66 kilogram from kilogram coal consumption (see wikipedia). As indicated in Table 15, the annual biogas production is 416 m^3, this means that the CO_2 emission production can be up to 0.48 kg per cubic meter biogas. Therefore, the total CO_2 emission for project activity can be computed as 8.51 million kilogram with the total biogas production of 17.73 million cubic meters (see Table 13). With the total coal consumption of 23.32 million kilogram (see Table 13), the CO_2 emission production can be taken to be 62.03 million kilogram in total, concerning the 2.66 kilogram

CO_2 production from 1 kilogram of coal. The CO_2 emission reduction for the project can be up to 53.52 million kilogram. The 1 kilogram CO_2 emission reduction costs can be estimated to be 0.044 RMB.

Thus, the GHG emission reduction costs of thermal energy between biogas and coal for individual household biogas digesters can also be estimated. This emission reduction costs must be similar to that for the whole biogas project. Figure 22 indicates the GHG emission reduction costs of thermal energy production in the biogas project, concerning individual digester with the size of 10 m^3.

Figure 22: GHG emission reduction costs of thermal energy production for 10 m^3 digester



Notes

①Costs of thermal energy production from biogas is equal to 556 RMB annually (see Table 16)

②Costs of thermal production from coal consumption as the same as produced from biogas are estimated to be 466 RMB, which is equal to costs of coal multiplied by coal consumption (relating Table 14 and 15)

③CO_{2e} emissions is taken the average of CH_4 emissions concerning 10 m^3 digester

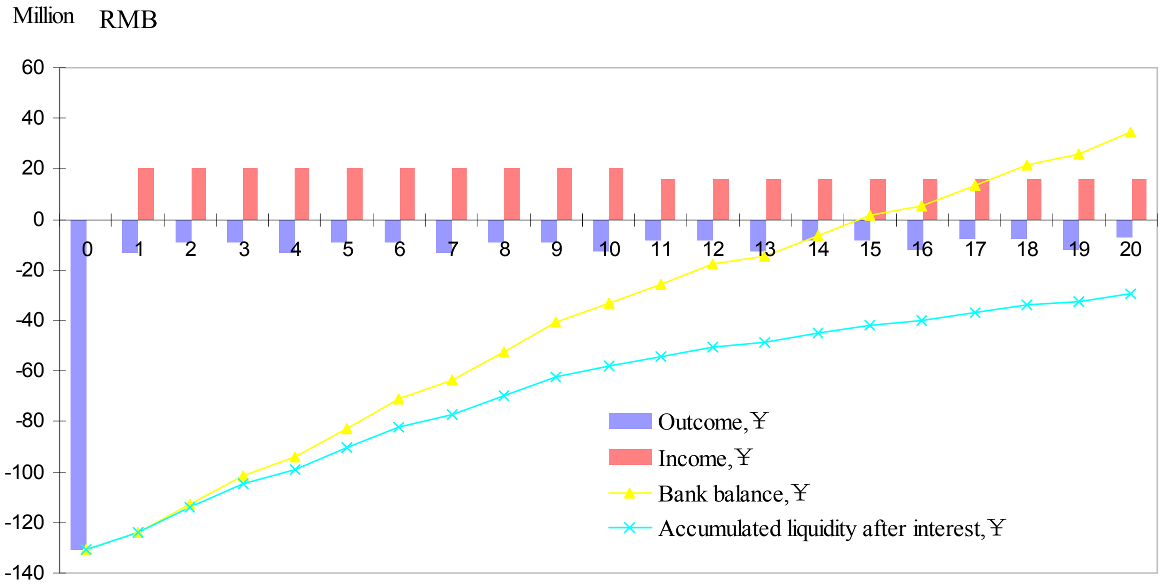
④CO_{2e} emissions are equal to CO_{2e} emissions from a kilogram of coal multiplied by coal consumption for the same thermal energy production from biogas

In Figure 22, the GHG emission reduction costs for digester with the size of 10 m^3 are similar that of the whole project, which are estimated to be 0.06 RMB/$kgCO_{2e}$. Thus, the costs of GHG emissions analysis for the whole project is presented in next part.

4.1.3.3 Cash flow and liquidity (with CERs)

Cash flow and liquidity are also very important economic analysis for biogas project, especially for this project, due to the unprofitability in the reference scenario. Thus, the investment costs consiste of biogas investment costs. Moreover, the CDM preparation costs would be proposed as maximum costs of 200,000 $ (1,500,000 RMB) (CDM project prospective, 2008). The annual outcome includes the project annual operating outcome without amortization costs, the annual substrates costs and the base rate for CDM preparation costs. The project income is separate from the revenue from thermal energy and the revenue from carbon dioxide. In this context the current price can be considered as 10 \$/t CO_{2e}. Thus, Figure 23 indicates the cash flow and liquidity of project activity.

Figure 23: Cash flow and liquidity of project activity with possible carbon income



In Figure 23, the total project investment of 130.62 million RMB is represented. In the zero year of the beginning of construction, the outcome is the total investment costs of 130.62 million RMB. The annual outcome calculates between 7.38 million RMB and 13.57 million RMB. In this case, the substrate costs must be taken into account, once the biogas digester begin to operate and the costs need also to be paid as the same amount for each of three years. Each year's income is computed to 20.48 million RMB. Consequently, the liquidity is estimated to be under zero. In order for the project to have balance of income and outcome as minimum wish, when the carbon price can be taken 142.4 RMB/CO_{2e} (see Annex 1).

Thus, the economic and ecological analyses complete for this household biogas project. The farmers can use substituted biogas to get thermal energy with the financial support from The World Bank and Chinese Countrypart Funding. Although the project can not accure profit even if it is a CDM project, but has ecological benefit, in term of GHG emission reduction are obvious. Futhermore, there are many biogas project not only for thermal energy production and utilization, but also for generated electricity. The next two sections in this chapter will make analyses for medium and large scale biogas electricity generation projects.

4.2 Economic and ecological analyses of medium scale dairy farm biogas electricity generation project

The economic and ecological analyses will be done for a medium scale biogas project with electricity production. For the analyses, two scenarios will be used for this project. The first Scenario is dealing with 20% dairy cattle manure from total waste that will produce biogas electricity and thermal energy for local company utilization, as well as rests, 80% waste for fertilizer production. Concerning the second scenario, 100% total waste will be disposed for biogas electricity generation for feeding into national grid, consequently produce thermal energy for local utilization.

4.2.1 Project background

Both electricity production and household thermal energy production from biogas are the main components for biogas utilization in China. Normally, for the livestock farms, the waste can be used to generate biogas for the production of electricity and thermal energy. In addition, due to the result of carbon dioxide emission reduction, the project investors may obtain more income from CER trading. The larger scale of the farms, the lower the costs of special investment on projects. Concerning the REL that established in 2006, the generated "green" electricity can be fed to the national gird (MOA, 2008). In this context, project owners obtain a bonus. However, the biogas electricity produced from smaller size livestock farms would have less chance of being fed into the network in comparison with the larger size farms. Consequently, the electricity-producing companies may have to face the instability problem in addition to the varying amount of biogas electricity production as well as also any negative effect for the network. That is the reason why in China, the medium scale farms with biogas production would rather be involved in generating biogas electricity and thermal energy production for local company utilization. Concerning these two arts of biogas utilization, when the farms have more electrical equipment for animal feed and factory production, the biogas project can be proposed for electricity generation and thermal energy production for use by local companies, and if there are some household located near the biogas project site, this biogas project can be constructed for thermal energy production and piped to surrounding countryside.

There is a biogas electricity project for a dairy farm located on the countryside of Jinhua city in Zhejiang province. The numbers of livestock at hand are 2,000 dairy cattle. From this number, there are 1,200 growth dairy cattle and 800 cultivated dairy. This project proposed to use 80% of the dairy cattle waste for composting and the rest, constituting 20%, can be used as substrate for biogas production, which could result in the production of fertilizer from composting and biogas electricity production from dairy cattle waste. In the absence of this project, the dairy cattle waste could be used as fertilizer for the orchard.

Thus, the biogas electricity produced can be used to power machines for milking system operation and other uses by the local company. The dung and urine production from one dairy cow account to 20 kg and 34 kg. Before the waste input into the biogas anaerobic digestion, about 80% of dry waste must be separated from the total waste for fertilizer production. Statistics from project data in MOA showed that with the dry matter of 18%, there were 32,000 kg dry waste that can be used for fertilizer production. The daily waste production of cow is indicated in Table 24.

Table 24: Daily dairy cattle waste production

	Daily cow, kg	Dry matter, %	Dry matter, kg	Proportion for composting, %	Proportion for biogas, %	For composting, kg	For biogas, kg
Dung	40,000	18	7,200	80	20	5,760	1,440
Emiction	68,000	3	2,040	100	100	-	2,040
Total	108,000		9,240			5,760	3,480

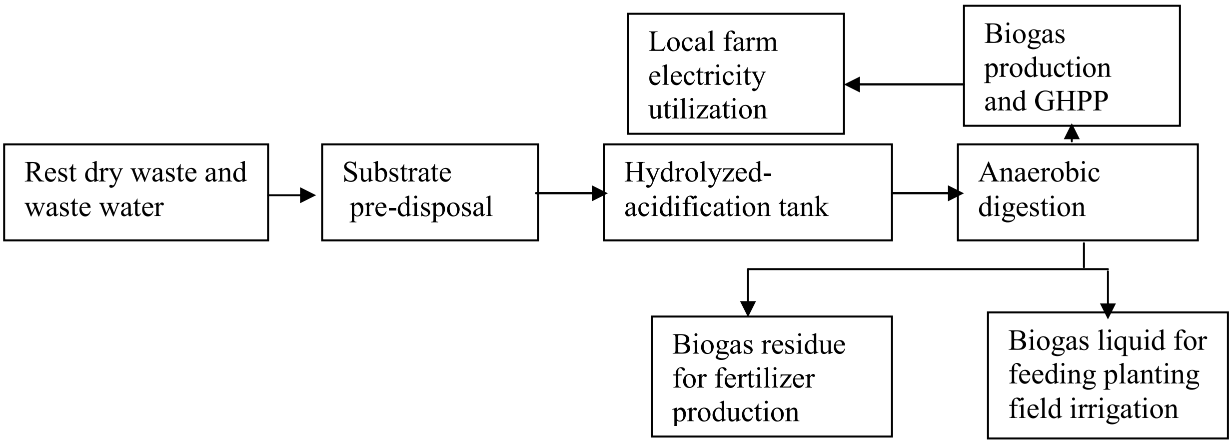
Source: MOA, 2006b

In Table 24, the daily cattle dung production is 20 kg, of which 18% dry matter can be considered. The emiction (urine) of dairy cattle can be regarded as 34 kg, from which only 3% constitute dry matter. Moreover, there is 50 kg washing water that can be required daily for cleaning waste. On the basis of this, the total dairy cow production as well as the dry matter of a dairy cow can be calculated. From the results of the calculation, there are 108,000 kg of dairy cattle waste annually. From this number, 9,240 kg are dry matter. Out of the dry matter, 5,760 kg are meant for composting and 3,480 kg for biogas production.

Thus, the 80% of dry waste must initially be separated from the total dung, emiction and waste water, so that it can be used to produce fertilizer. Not only the separated dry waste can be disposed for fertilizer production, but also the biogas residue can be taken after biogas production in anaerobic digester. Both dry waste and biogas residue have some water content. This explains why the saw dusts and straw can be used as co-substrates for the moisture rate to decrease after cutting them into pieces. In terms of biogas production, the substrates and co-substrates must be mixed completely. After substrates preparation, all substrates must be fermented and milled aerobically. Then the substrate must be decomposed and fermented. The output after decomposition and fermentation could be used to irrigate the orange orchard, packed and sold in the market.

Concerning the project plan, the 20% of dry waste, cattle emiction and waste water can be considered as substrate for biogas electricity production. The operating process indicates in Figure 24.

Figure 24: Biogas electricity generation operating system



Source: MOA, 2006b

After the description of substrate preparation and biogas electricity generation operating system, the initial project investment costs must be studied. Thus, the estimated investment costs naturally cover the biogas electricity production and fertilizer production, which included the costs for construction and the costs for equipment. In this context, the investment costs for the construction part of the project are indicated in Annex II-1. Thus, the total investment costs can be estimated to 1,165 thousand RMB including the costs for biogas electricity project, 965 thousand RMB for fertilizer production and 119 thousand RMB for outside project construction (see Annex II-1). In addition, there are also some investment costs for the equipment. These costs are presented in Annex II-2. Concerning Annex II-2, the equipment costs for the biogas electricity generation project under the condition in Scenario I assume to 962 thousand RMBand 363 thousand RMB for organic fertilizer (see Annex II-2). Thus, the total costs of material construction and equipment purchase for biogas electricity generation project assume 2,127 thousand RMB and 1,328 thousand RMB for the organic fertilizer project. There are also some costs for project design, debugging costs and unforeseeable costs. These costs are illustrated in Table 25.

Table 25: Total costs calculation for biogas electricity generation project and organic fertilizer project. (Scenario I)

Project	Material construction costs (I)	Equipment costs (II)	Total costs (I+II)	Project design costs①	Debugging costs②	Unforeseeable costs③	Total costs
	Thousand RMB						
Biogas electricity generation	1,165	962	2,127	85	43	106	2,361
Organic fertilizer production	965	363	1,328	53	27	66	1,474

Source: MOA, 2006b

Notes:

① Project design costs are calculated from 4% of summarized construction costs and equipment costs

② Debugging costs are accounted from 2% of summarized construction costs and equipment costs

③ Unforeseeable costs are estimated from 5% of summarized construction costs and equipment costs

Thus, the total costs for electricity generation project are 2,361 thousand RMB. This can be considered as Scenario I. Actually, if the electricity produced could be fed into the network, it can be proposed that 100% dairy cattle waste and waste water can be entirely used for biogas production. In this case, the total dairy waste (40 kg of dung and 68 kg of emiction, 100 kg of waste water for cleaning), mean 208 kg dairy waste and waste water for biogas production. From the total 208 kg waste daily production as substrates, the dry matter of these 208 kg is absolutely higher than that from the substrates comprised of 8 kg of dung, 68 kg emiction and 100 kg waste water daily. As a result, the biogas can be produced more simultaneously with the production of more electricity. This can be proposed as project operation in Scenario II.

In order to get the economic analysis for the proposed idea, the investment costs must be calculated. For the investment costs estimation, the project costs concerning Scenario I can be taken as the point of reference (see Annex II-1 and 2). Based on the data in the project costs for Scenario I changes in the investment costs under the condition of Scenario I and II is calculated in Table 26, 27 and 28. Concerning the costs project construction for Scenario II, Table 26 explains the changing.

Table 26: Investment costs changing for the project construction (Scenario I and II)

	Project construction	Size	№ for SI	№ for SII	Price	SI: Total price	SII: Total price
		m^3			RMB/m^3,m^2	Thousand RMB	
5	Anaerobic digester	600	**2**	**5**	550	**660**	**1,650**
6	Steel plate for anaerobic digester		**2**	**5**	30,000	**60**	**150**
9	Biogas storage cabinets	450	**1**	**5**	330	**150**	**750**
	Total (5+6+9)					870	2,550
	Total (others)					295	295
I	Total costs					1,165	2,845

Considering Table 26, some of the costs from construction, equipment changed. In this conctext, the construction costs for anaerobic digester for Scenario II are higher than 1,800 m^3, whose costs have also increased 990 thousand RMB. The reason is that in Scenario I, there are only 8 tons dairy dung and water daily used for biogas production. For the proposed Scenario II, the dairy dung produces 40 tons daily and also plus the same amount of emiction and waste water. Moreover, for the fermentation calculation, with the calculation of 3 kg oTS for daily biogas production in the anaerobic digester (Fachagentur Nachwachsende Rohstoffe e.V., 2006), the daily biogas anerobic digester size has increased from 360 m^3 to 1,800 m^3 in Scenario II. Concerning the same amount digester size for liquid substrates (emiction and waste water) of 840 m^3 (the difference between 1,200 m^3 and 360 m^3), the anaerobic digester for Scenario II must take more volume which the substrates input requires and it accounted for 2,640 m^3 (the sum of 1,800 m^3 and 840 m^3). So, as the planned digester size of 600 m^3, the number of digesters in Scenario II must be 5 units, and the price for an anaerobic digester is computed to be 1,650 thousand RMB. In addition, the number of steel plate for an anaerobic digester is also increased to 5 pieces and have also been computed to be 150 thousand RMB. The biogas storage cabinets have consequently also increased to 2,250 m^3, and the price, 75 thousand RMB. In this case, the total price for Scenario II is calculate to be 2,845 thousand RMB in comparison with the costs of 1,165 thousand RMB for Scenario I (see Table 26). The investment costs change for Scenario II concerning project equipment are indicated in Table 27.

Table 27: Investment costs changing concerning project equipment (Scenario I and II)

	Project equipment	№ for SI	№ for SII	Price	SI: Total price	SII: Total price
				Thousand RMB		
4	Temperature control system for anaerobic digester	2	5	30	**60**	**150**
6	Biogas electricity generation	1/0	3/1	60/20	**60**	**200**
18	Anaerobic digester insulation layer	2	5	40	**80**	**200**
	Total (4+6+18)				**200**	**550**
	Equipment construction				**88**	**123**
	Total (others)				**675**	**675**
II	Total				962	1,347

Table 27 shows the equipment costs changing. The temperature control system in an anaerobic digester is required to be increased from 2 pieces to 5 pieces. This explaines why the prices increase from 60 thousand RMB to 150 thousand RMB. Moreover, it is very important that the biogas electricity generation in Scenario II can produce electricity five times more than Scenario I. In this context, for a complex CHPP, the price is 60 thousand RMB, and as the default number of biogas electricity production for Shandong Shengdong National Co.Ltd, the price is increased less than three times, if the installed capacity taken of less 200 kW. Furthermore, for the anaerobic digester insulation layer, in Scenario II three pieces for 120 thousand RMB can be taken. Last, the equipment construction costs must also be considered. As a result, the total costs for equipment are accounted for 1,347 thousand RMB in Scenario II compared to that of 962 thousand RMB in Scenario I (see Table 27). Thus, the total costs for biogas electricity production project are indicate in Table 28.

Table 28: Total costs calculation for biogas electricity generation project (Scenario II)

Costs for Project construction	Costs for Equipment	Total costs	Costs for project design ①	Debugging costs②	Unforeseeable costs③	Total costs
Thousand RMB						
2,845	1,347	4,192	168	84	210	**4,653**

Notes:

① Project design costs are calculated from 4% of summarized construction costs and equipment costs

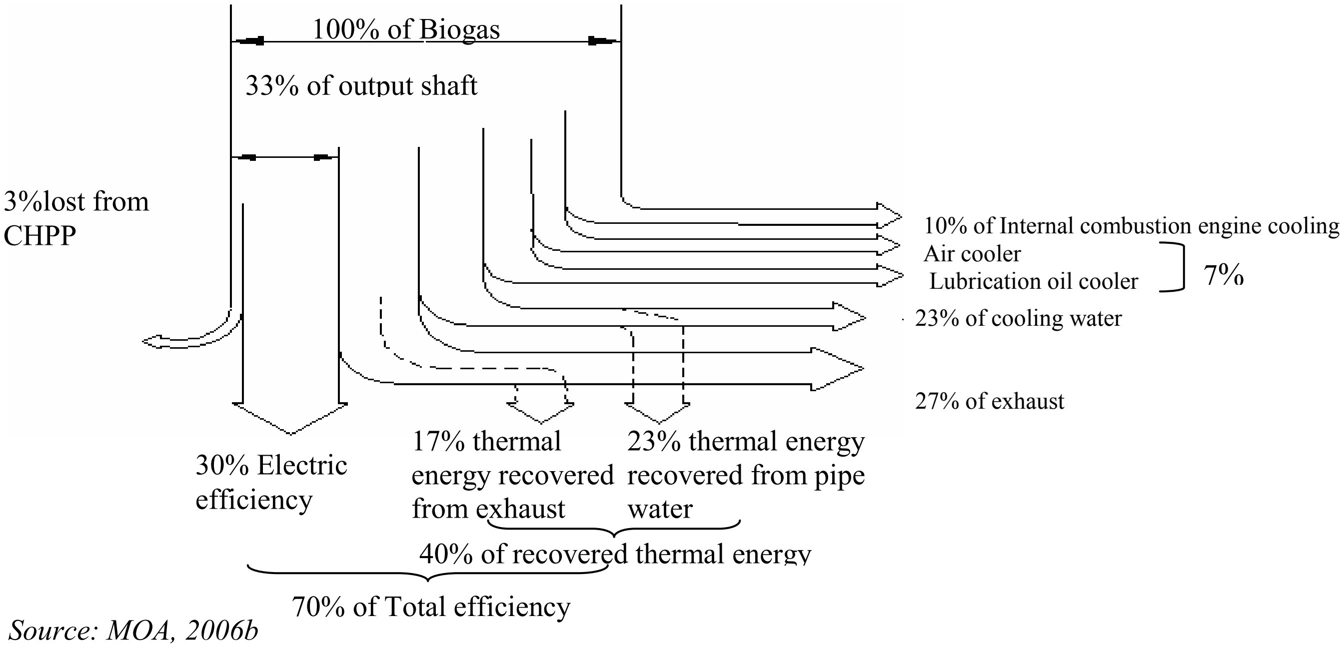
② Debugging costs are accounted from 2% of summarized construction costs and equipment costs

③ Unforeseeable costs are estimated from 5% of summarized construction costs and equipment costs

Furthermore, Table 28 indicates the total costs with the additional calculation of project design costs, debugging costs and unforeseeable costs. The total costs are 4,653 thousand RMB in Scenario II (see Table 28).

For both scenarios, an important data is the biogas electricity generation operates with 30% of electric efficiency and 40% of thermal energy efficiency. The biogas electricity generation energy balance is indicated in Figure 25.

Figure 25: Biogas electricity generation energy balance



Source: MOA, 2006b

Figure 25 indicates the biogas electricity generation with reference to China and its associated combusting pure biogas with the internal combustion engine. Besides this kind of biogas electricity generation, there is also the alteration of the diesel plant for biogas electricity generation that combusted biogas and a little diesel. The biogas electricity generation with a gas turbine, this promoted post-combustion biogas directly to drive the impeller in a gas turbine generators to produce electricity. The electricity produced can be used for milling machines and company office utilization. The thermal energy can also be used by the local company. Moreover, the thermal energy production should be used more in summer than in winter. It must, however, be noted that the lower temperatures occur in winter. Even though the anaerobic digester has an insulation layer, the thermal energy would be consumed to keep temperatures lower during summer than for heating in winter. It is also interesting to note that the average temperature could be around 35°C in summer and 10°C in winter. Thus, after introduction of project background, the economic and ecological analyses will be presented.

4.2.2 Economic analyses

In this part, the economic analyses with different methodologies will be made for this biogas electricity production project. This project includes two scenarios. The first Scenario is for biogas electricity production for local company utilization. The second is biogas electricity production for feeding into the national grid.

4.2.2.1 Cost-revenue analysis

For the economic evaluation, the first step is to determine the annual imputed costs and generated revenue. As indicated in Chapter 3.1, the annual costs include interest charges, amortization costs, costs of repair, cost of insurance, costs of payment of salaries, process energy costs and other costs. With the total costs of 2,361 thousand RMB, the interest charges can be taken 5.76% from the total investment costs. The amortization costs are estimated to be within the 20 year period for the project lifetime. The costs of repair and costs of insurance are estimated to be 5.5% of repair factor and 0.5% of insurance factor. Only two workers might be required for the project with an annual salary of 20,000 RMB. The process energy costs can be estimated to be 7% of investment costs. Other unforeseeable costs are considered to be 2% of investment costs. The cost calculation is presented in Table 29.

Table 29: Annual imputed costs evaluation for Scenario I

Conponents, RMB/a	Value
Interest charges① 5.76% of investment costs	84,180
Amortization 3 years of lifetime for CHPP;5,8 and 10 years of lifetime for equipments	122,284
Costs of repair 5.5% of investment costs	129,855
Costs of insurance 0.5% of investment costs	11,805
Costs of payment of salaries	20,000
Process energy costs	10,761
Other costs	47,220
Total annual imputed costs	426,106

Notes::
The investment sum was taken 2,361,000 RMB
① *The bank loan could be considered as 5.76%, the interest charges had been calculated with the capital commitment of 61.9%*

Table 29 shows that the project owner needs to pay attention to costs concern equipment repair and amortization costs. Next, the interest charges can not be ignored. Moreover, the project owner must also pay the workers' salaries and other unforeseeable costs. Thus, the total annual imputed costs are estimated to be 426 thousand RMB.

After annual imputed costs evaluation, the revenue also needs to be calculated. The revenue can be divided into two parts- the electricity and heat production for local company utilization. The electricity efficiency is estimated to be 30% of total energy production, and 40% efficiency for thermal energy production. Out of the total thermal energy produced, only 25% are use for consumption by the local company. Moreover, the average price of electricity in this province is 0.52 RMB per kilowatt hour and because the electricity will not be fed into the network, the biomass bonus 0.25 RMB/kWh$_{el}$ can not be obtained. The price for thermal energy consumption is the same as that for the thermal energy from coal consumption. This price of thermal energy is estimated to be 0.133 RMB per kilowatt hour. Table 30 indicates the electricity and heat production and annual revenue for the project.

Table 30: Annual electricity and heat production, revenue calculation for Scenario I

	Unit	Value
Net electricity energy	kWh$_{el}$/a	295,650
Net heat energy	kWh$_{ther}$/a	98,550
Electricity price	RMB/kWh$_{el}$	0.52
Renewable energy bonus	RMB/kWh$_{el}$	0
Coal price	RMB/t	1,080
Energy content of coal	kWh/t	8,130
Heat price	RMB/ kWh$_{ther}$	0.133
Annually revenue		In RMB
Electricity for local utilization		153,738
Heat utilization in local		13,091
Heat selling		0
Total revenue		166,830

Thus, in Table 30, the electrical energy production is 295.65 thousand kilowatt hour annually and 98 55 kilowatt hours for thermal energy production. The annual total revenue are 166.83 thousand RMB. Thus, the project has a loss of 259.28 thousand RMB. This is because the biogas electricity project is on a smaller size. With a farm scale of 2,000 dairy cattle, only about 20% of total annual dung is used for biogas production. In this context, the total electrical energy produced is low and only use for local consumption.

However, if all of the dairy waste and waste water can be used for biogas production for the generation of electricity with the view of feeding into the national grid, the economic situation must be better than when only 20% of dairy dung used for biogas production (Scenario I). In this context, like the Tables 26, 27 and 28 show, if all farm waste were used to generate biogas electricity, the total costs could be 4,653 thousand RMB. The investment costs in this scenario (Scenario II) will only be one and half times more than the costs for Scenario I, but the biogas production could be more than four times. According to the proposed investment costs for Scenario II in Table 28, the annual costs and revenue are presented in Table 31.

Table 31: Annual imputed costs evaluation for Scenario II

Conponents, RMB/a	Value
Interest charges① 6.8% of investment costs	195,859
Amortization 3 years of lifetime for CHPP,5, 8 and 10 years life time for equipments	204,469
Costs of repair 5.5% of investment costs	255,922
Costs of insurance 0.5% of investment costs	23,266
Costs of payment of salaries	30,000
Process energy costs	53,808
Other costs	93,062
Total annual imputed costs	856,386

Notes:
The investment sum was taken 4,653,120 RMB
① *The bank loan could be considered as 6.8%, concerning the 5.76% for long-term deposit and bank loan 7.65%, the interest charges had been calculated with the capital commitment of 61.9%*

In Table 31, the costs situation is more or less like that of Scenario I. The Figure for total annual imputed costs is 856.39 thousand RMB. Only the project owner must pay more than in Scenario I. However, in this case, the revenue should be also more.

After annual costs evaluation, the next step is to determine the annual revenue. With the larger amount of biogas production in Scenario II, the biogas electricity generation production will also be increased, just as is the case in Scenario I. In addition, the price of electricity for feeding into the national grid can be 0.32 RMB[10] per kilowatt hour and the 0.25 RMB as biomass bonus per kilowatt hour. Consequently, the thermal energy should also be increased. However, the thermal energy utilization for the local company must be as same as in Scenario I. Moreover, the thermal energy price of 0.133 RMB per kilowatt hour should also be considered as the same as in Scenario II. The annual revenue for Scenario II is indicated in Table 32.

---

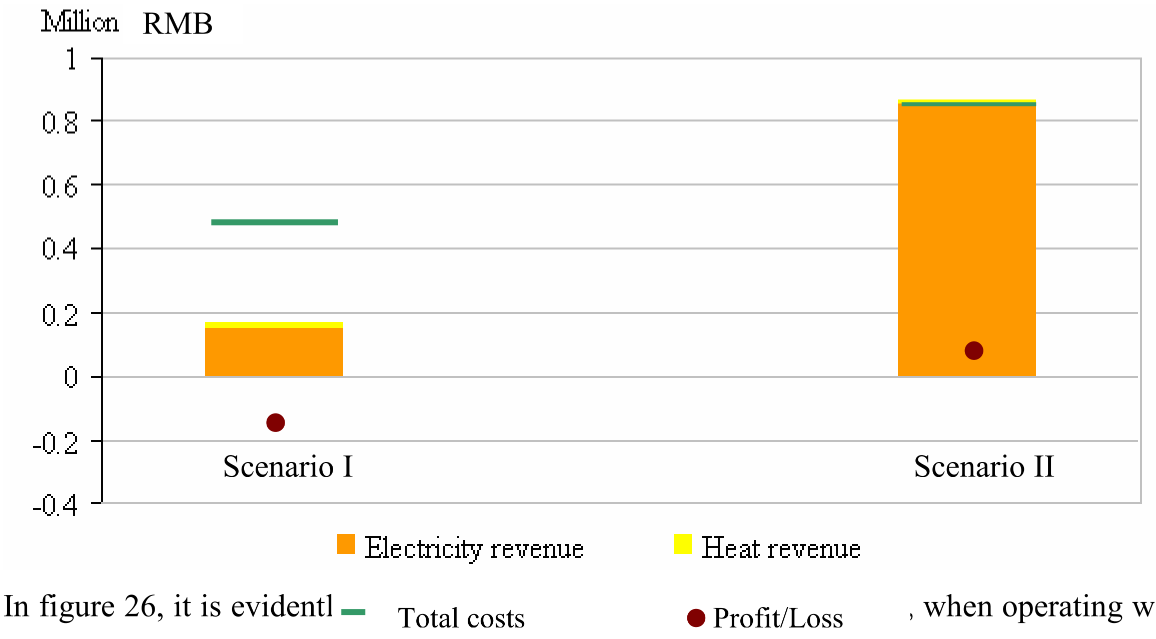
[10] 0.32 ￥/kWh_{el} is the price of electricity for feeding into national grid in Zhejiang province.

Table 32: Annual electricity and heat production, revenue calculation for Scenario II

	Unit	Value
Net electricity energy	kWh_{el}/a	1,478,250
Net heat energy	kWh_{ther}/a	98,550
Electricity price	RMB/kWh_{el}	0.33
Renewable energy bonus	RMB/kWh_{el}	0.25
Coal price	RMB/t	1,080
Energy content of coal	kWh/t	8,130
Heat price	RMB/kWh_{ther}	0.133
Annually revenue	RMB	
Electricity for local utilization		857,385
Heat utilization in local		13,091
Heat selling		0
Total revenue		870,476

The electrical energy is produced with amount of 1.48 million kilowatt hours. Thermal energy in this context is accounted for 492.75 thousand kilowatt hours. In reality, 0.98 million kilowatt hours thermal energy can be used by the local company. Thus, the revenue for the sale of electrical energy is substantially more than that for local company utilization (Scenario I). Although the revenue for thermal energy utilization is as the same as that for Scenario I the total revenue are estimated to be 870,476 thousand RMB annually. In the case of Scenario II, the project can be have accrued a profit of 14,091 thousand RMB. Thus, the result for the comparison between Scenario I and Scenario II is illustrated in Figure 26.

Figure 26: Costs, revenue and profit/lost situation for Scenario I and II



In figure 26, it is evidentl , when operating within the framework of Scenario II compared to that of Scenario I. It must, however, be noted that the project operates within the parameters of Scenario II have a small profit margin. The reason is why the project can operate much better under the condition of Scenario II. Compared to that of Scenario I, the volume of biogas production in Scenario II is four times more than that in Scenario I. It is also due to the fact that there is four times more dairy cattle waste in Scenario II than in Scenario I. That also explains why the generated electricity in Scenario II is four times more compared with that in Scenario I[11].

Futhermore, the investment costs for Scenario II are almost two times more than that of Scenario I. Despite the fact that investor needs to pay the interest charge to the bank, the generated electricity can have a greater opportunity fed into the national network. In that context, the project under Scenario II can obtain a biomass bonus. This can be substantiated with the fact the biomass bonus might be one of the most sensitive factors for this biogas project. The factors which actually have greater influence on the project must be analysed in future.

Thus, after cost-revenue analysis, the following analyses concerning sensitivity, Break-even, the“worst”, “normal” and “best” cases analyses, as well as “Monte-Carlo-Simulation” will be presented.

4.2.2.2 Sensitivity analysis

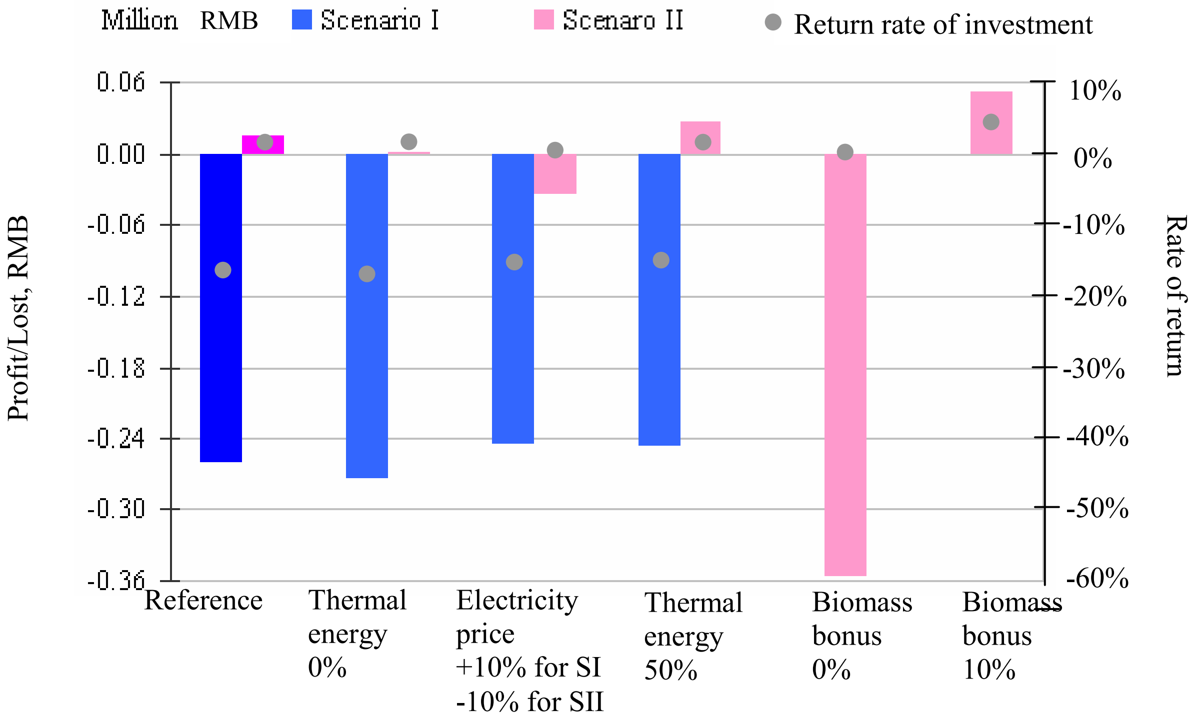
Concerning the procedure for writing the study, the sensitivity analysis will be estimated for both scenarios. The project profit is -233 thousand RMBfor Scenario I and 15 thousand RMBfor Scenario II. However, the result can be changed. For instance, if the thermal energy were not used, both scenarios would have run at a loss. Moreover, the price for electrical energy could also be a sensitive factor for both of scenarios. If the price for electrical energy were increased by 10% for the Scenario I, the profit for this scenario would still have been under zero. If the price for electrical energy were -10% for Scenario II, the project would have been unprofitable. In addition, if 50% of thermal energy were used from the total thermal energy production, the profit would have been increased. Considering the same rate of thermal energy utilization in Scenario II, the profit margin rose higher than in the reference scenario. Unfortunately Scenario I cannot receive a biomass bonus, because there is a very little opportunity for the generated electrical energy to be fed into the national grid. This might have also been the case for Scenario II. In view of this, if the biomass bonus was not

---

[11] The generated electricity can be considered in terms of the biogas production under other equal conditions

considered for the Scenario II, it would have run at a loss. In case the biomass bonus were increased by 10%, the profit would have been increased more annually. In this case, the return rate of investment would also changed concerning the change in results for both scenarios (see Annex II-3). The detailed information is found in Figure 27.

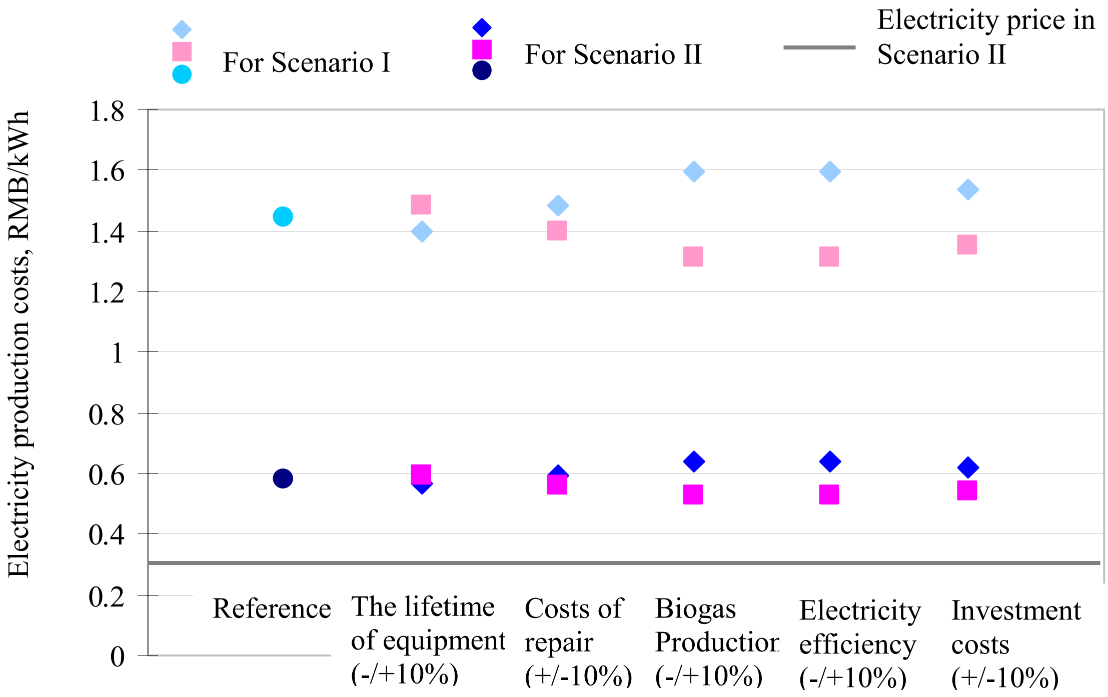
Figure 27: Sensitivity analysis and return rate of investment for scenarios I and II



Thus, as seen in Figure 27, there is no chance for Scenario I to make a profit. Neither the price of increased electricity, nor thermal energy utilization increaseed to 50%. In the case without thermal energy utilization, the result is even worse. Thus, about -245 thousand RMB are obtained. Scenario II can operate much better, especially when the biomass bonus is increased by 10%. In this context, the project operated within the framework of Scenario II, accruing more profit. Moreover, considering the reference cases for both scenarios, the thermal energy utilization is earmarked to be 25% of the total thermal energy production. If this proportion had been doubled, the project would have also achieved a positive result in the case of Scenario II. In the event that the project operated had operated without thermal energy utilization and a biomass bonus, the results would have been much lower. In this case, if the project were operated under condition in Scenario II without a biomass bonus, the results would tend to be discouraging.

The sensitivity analysis can also be estimated for scenarios I and II, if the amortization costs, costs of repair, biogas production, electricity efficiency, investment costs changed, and the biomass bonus would have been changed in Scenario II (see Annex II-4). Figure 28 illustrates sensitivity analysis for scenarios I and II.

Figure 28: Sensitivity analysis for scenarios I and II

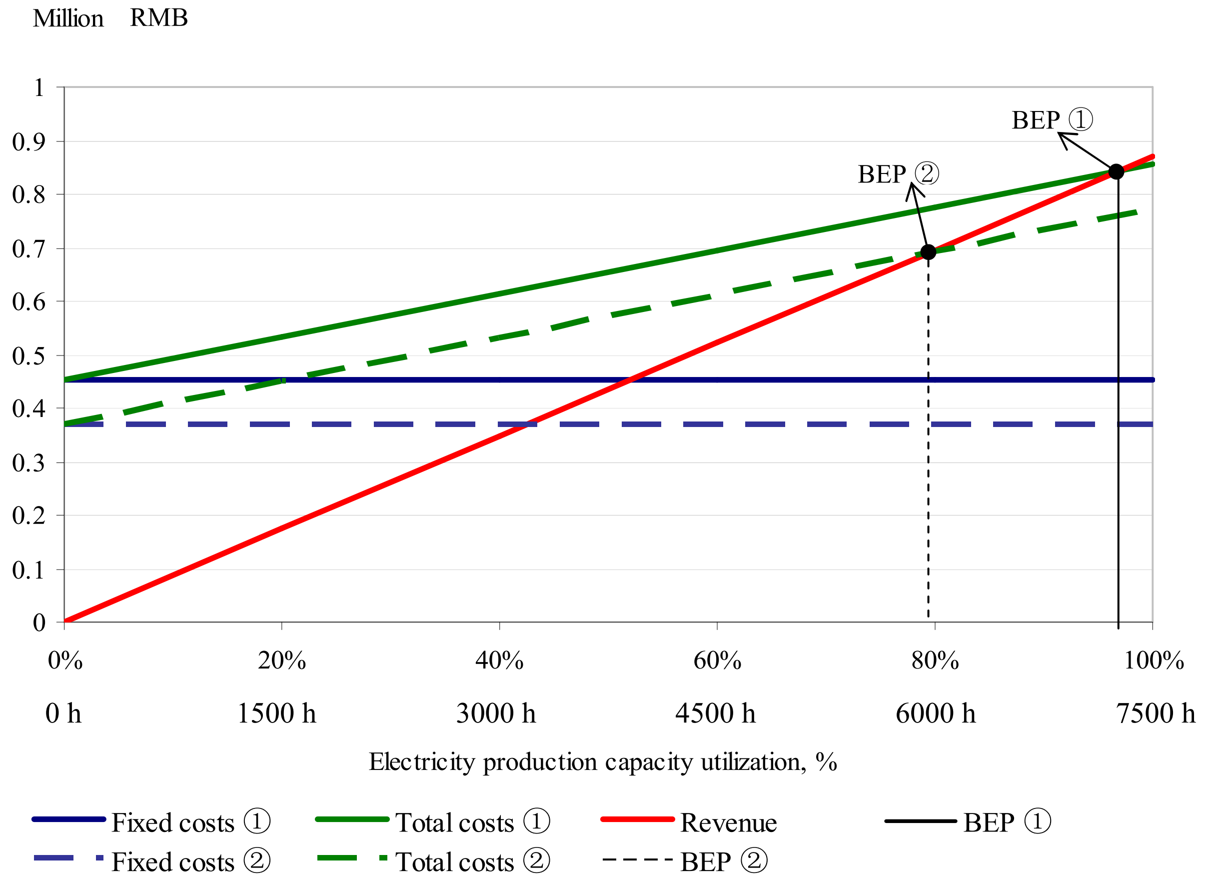


Considering Figure 28, the biogas production and electricity efficiency are the most sensitive factors for both Scenario I and II. In this context, an increase in either biogas production, or increase electricity efficiency, the project could have better results. It is interesting to know, although the amortization costs and costs of repair are the largest costs for both scenarios, these factors are not sensitive than other factors in reality. Furthermore, one also needed to have considered the selling price of electricity production. 0.33 RMB is the actual price for the sale of electricity per kilowatt hour for Scenario II. This is depicted with a grey colour in the diagram. Thus, if this medium scale farm could have produced electricity for feeding into the national grid and at the same time, the investors could have obtained a biomass bonus, the project could have been operated at a lower cost of electricity with the surety of accruing profit.

4.2.2.3 Break-even analysis

After sensitivity analysis, the Break-even analysis must also be estimated. This can help estimate the balance between profit and loss. Due to the unprofitability nature of Scenario I, the Break-even analysis will only be performed for Scenario II. First, the fixed costs and variable costs must be calculated. Thus, the fixed costs include the interest charge, amortization costs; costs of insurance and costs of payment of salaries. The variable costs include repair, process energy and other costs. If the generated electricity utilization were estimated to be from 0 to 100%, the variable costs would also changed from 0 to 100% of variable costs as seen in the reference case. The revenue can also be estimated referring the change of generated electricity utilization. This calculation is presented in Annex II-5. Thus, Figure 29 illustrates the Break-even analysis.

Figure 29: Break-even analysis for Scenario II



Notes:
① Project operated under condition of reference case for Scenario I and II
② Project operated under condition of reference case for Scenario I and II. Only the lifetime of CHPP was estimated to be 5.3 year, which had twice more than reference scenario

In Figure 29, the x axis indicates electricity production capacity utilization. This can be regarded as from 0 hour to 7,500 hours per year. The fixed costs have stabilized. This is shown with the blue line. The total costs increase depending on the electricity production capacity utilization. This is depicted with a green line in the Figure 29. The revenue can increase simultaneously with the capacity for electricity production. Thus, the point of intersection between total costs and revenue is called Break-even point. This shows the balance between profit and loss. Concerning Figure 29, when the electricity generation capacity was 97%, the project attained the Break-even point. This means the biogas plant should operate at leat 7,275 hours to be able to balance costs and revenue.

Moreover, the CHPP's lifetime are estimated to be 2.67 years, which is two times less compared with some foreign CHPPs. If this lifetime were doubled, the amortization costs would be nearly 1.7 times lower than it in reference scenario. In effect, the total costs and fixed costs can also be decreased. This is presented in the Figure 30 with the green and blue line dashes.

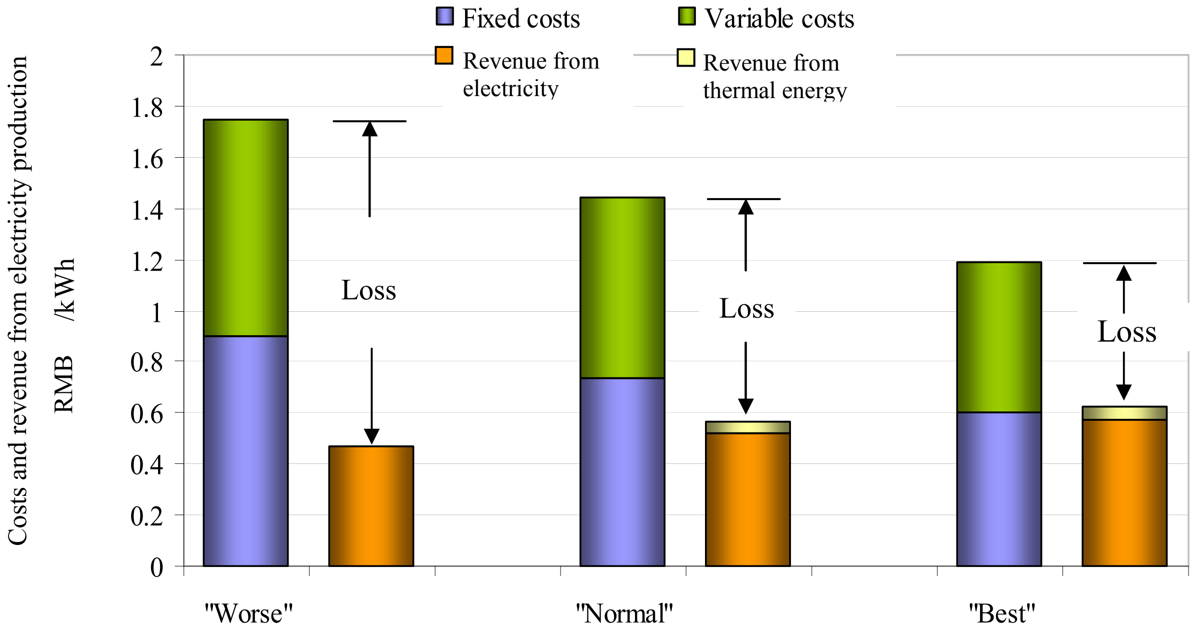
However, the variable costs would be equal to that in the reference case. In this context, the break-even point could be shifted to left side and it would have meant that the electricity generated utilization capacity could be nearly 80%, that means nearly 6,000 hours operation time per year.

In the next section the "worst", "normal" and "best" cases analyses will be presented. This may brings project owner a forecast, either to advoid most factors/parameters that run badly or accrue more income with effeicient project operation and management.

4.2.2.4 The "Worst", "normal" and "Best" cases analysis

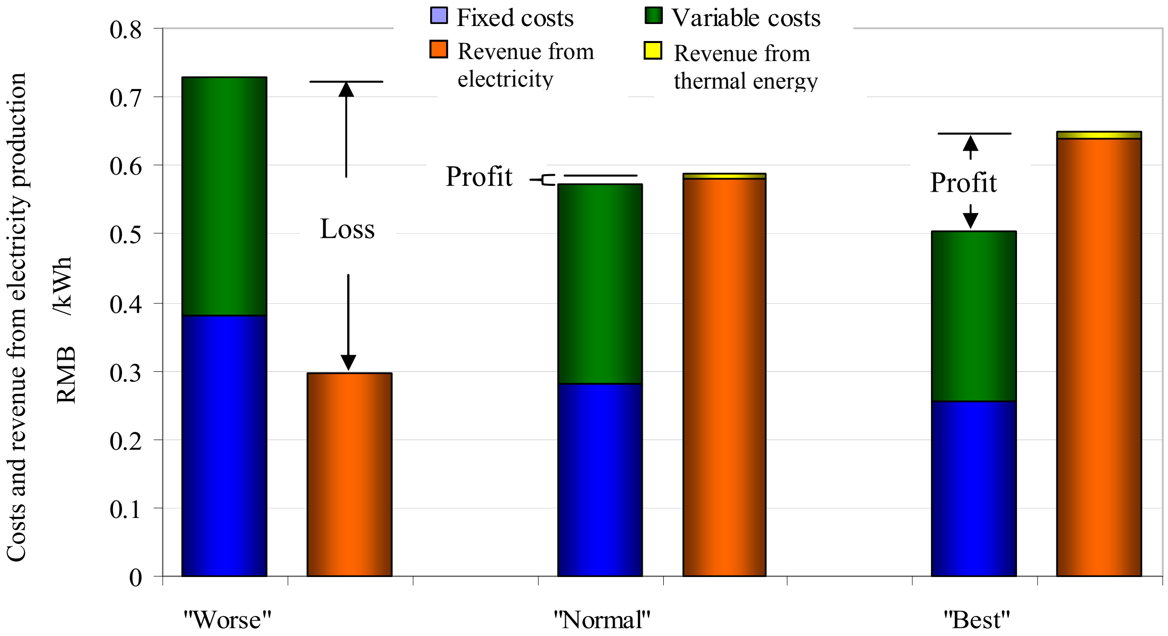
Although the Scenario I is unprofitable, the worst, normal and best cases can be evaluated economically. Thus, all costs can be estimated for the electricity generation. The revenue from electricity and thermal energy can also be evaluated with the amount of electricity. The detailed calculation is presented in Annex II-6 and 7 for Scenario I and for Scenario II. Figure 30 and 31 illustrate the worst, normal and best cases for scenarios I and II.

Figure 30: “Worst”, “normal” and “best” cases analysis for Scenario I



In Figure 30, for the worst case, the biogas production was estimated to be 90% of that in reference scenario. Amortization costs, costs of repair are estimated to be about 110% of costs in the reference case. In addition, the total energy generation is determined in absence of thermal energy utilization. The project operating with “worst” case scenario runs at a loss. For the “best” case, the change in costs only concerns the initial sum of investment. However, the project cannot obtain profit in these cases. Whenever, the biogas production increases by 10% compared with that of reference scenario, the price of electricity is increased by 10% and exceeds thermal energy utilization increase by 5% compared with that in reference scenario. The project operates with Scenario II is better than Scenario I (see Annex II-7). Figure 31 indicates the “worst”, “normal” and “best” cases for Scenario II.

Figure 31: “Worst”, “normal” and “best” cases analysis for Scenario II



As seen in Figure 31, the costs for “worst” case are estimated to be 0.16 RMB for each kilowatt electricity generation compared with “normal” case. The revenue obtains with 10% decrease in electricity production a 10% lower price. Moreover, the project with “worst” case operates without thermal energy utilization. As Figure 37 shows, the loss is 0.43 RMB for each kilowatt hour electricity generation. There is a little profit can be accrued in “normal” case. Thus, for the “best” case, with 10% lower investment costs and 10% higher biogas production, as well as 10% increasein the price of electricity generation, the project accrues a profit of 0.18 RMB for each kilowatt electricity generation.

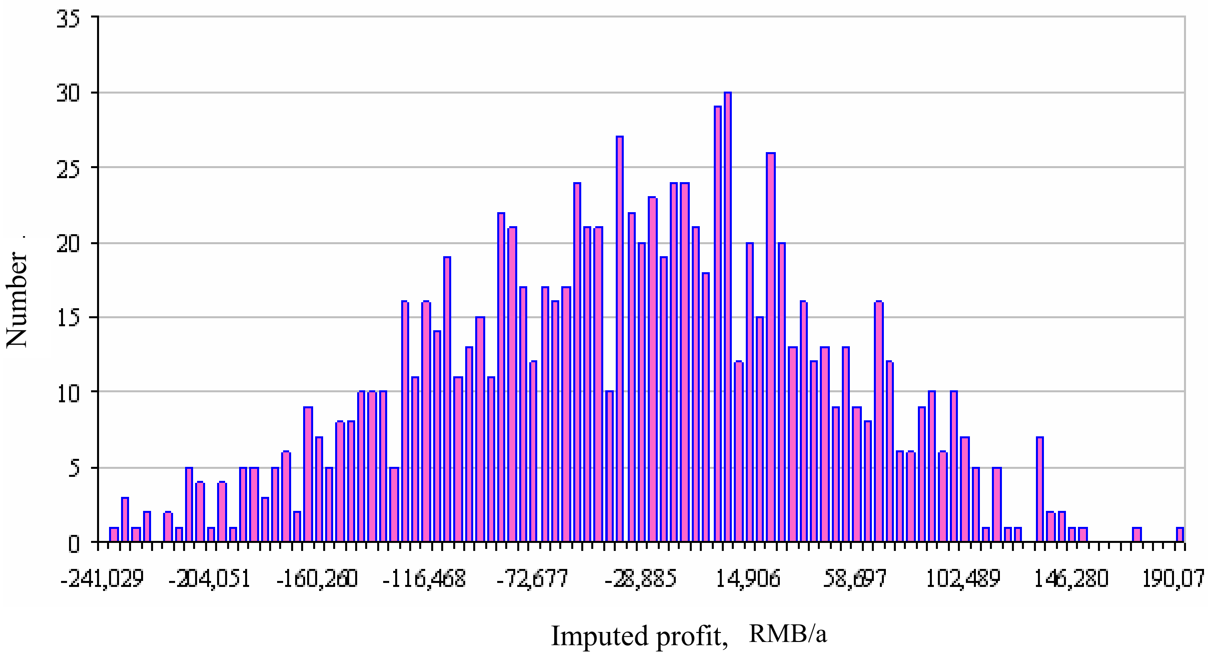
As a result of economic analysis, the Scenario I has a loss and Scenario II make a profit. From this analysis, the investment costs, biogas production, as well as price of electricity are sensitive factors, for example. Thus, it could be very important to estimate the influence of every factor on project operation, so that the project owners can avoid the project risk. In the next part, the Monte-Carlo-Simulation will be analysed concerning the risk analysis for project.

4.2.2.5 Monte-Carlo-Simulation risk analysis

Thus, after some economic analyses concerning methodologies, finally, evaluation must be carried out for the Monte-Carlo-Simulation concerning the procedure for analysis. Scenario I has no prospect of accruing profit. For that reason, the Monte-Carlo-Simulation risk analysis cannot be carried out for Scenario I. But the Monte-Carlo-Simulation would be made for Scenario II, despite the fact that the profit margin is low. The first step within the context of the Monte-Carlo-Simulation is to determine every factor for cost-revenue evaluation. The planning of every factor for the Monte-Carlo-Simulation must be done for the density function. This density function can be considered as input for Monte-Carlo-Simulation risk analysis. The output of Monte-Carlo-Simulation is illustrated after programming with the profit/lose density function and distribution function. This description can be considered to Chapter 3.2.1.

Thus, compared to the methodology (see Chapter 3.2.1), both density and distribution functions can be interpreted to access the prospects of the project accruing profit. These calculations are indicated in Annex II. Moroever, the density and distribution function are also presented in Annex 2. For the detailed explanation of the profit/loss risk analysis see Figures 32 and 33.

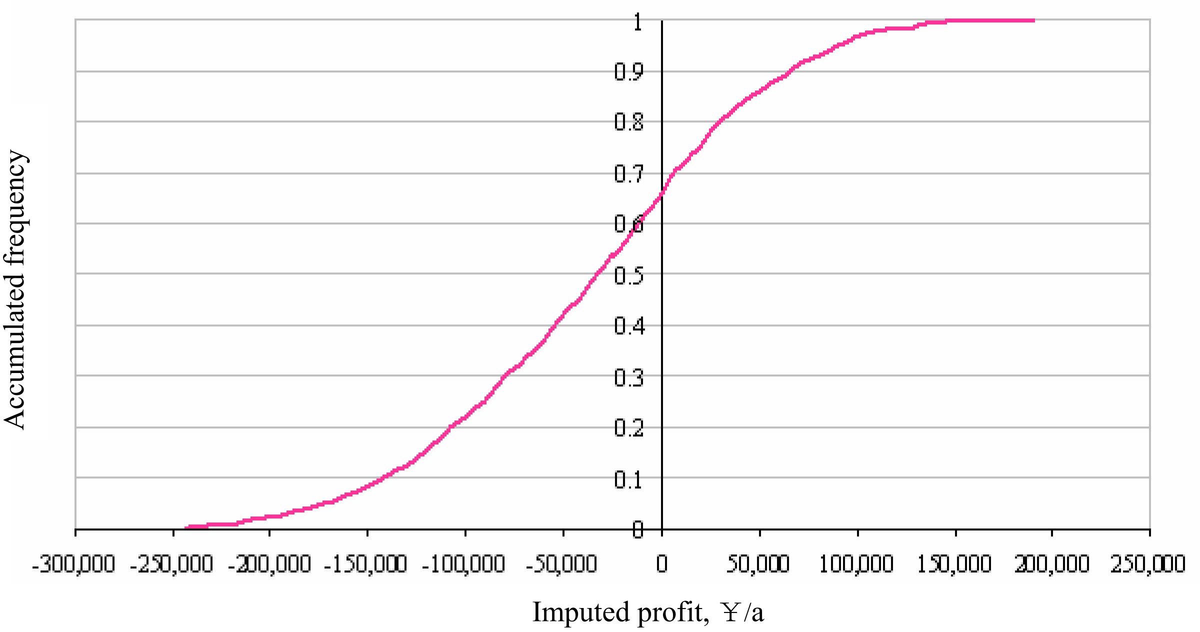
Figure 32: Density function of biogas project with Scenario II



Source: own calculation based on the data from Rauh, 2008

In Figure 32 the maximum profit value of 190 000 RMB and minimum profit value of -241 029 RMBannually is illustrated. Between 14 906 RMB to -72 677RMB the biogas has a greater probability of getting results. Considering the distance, the density function has more numbers than there are in other locations in the diagram. This project was worthwhile, though the prospect of accruing profit was low (see Annex 2). Thus, the frequency of accruing profit is regarded as the important part for the Monte-Carlo-Simulation. The Figure 33 indicates the frequency of accruing profit for this project.

Figure 33: Distribution function of biogas project with Scenario II

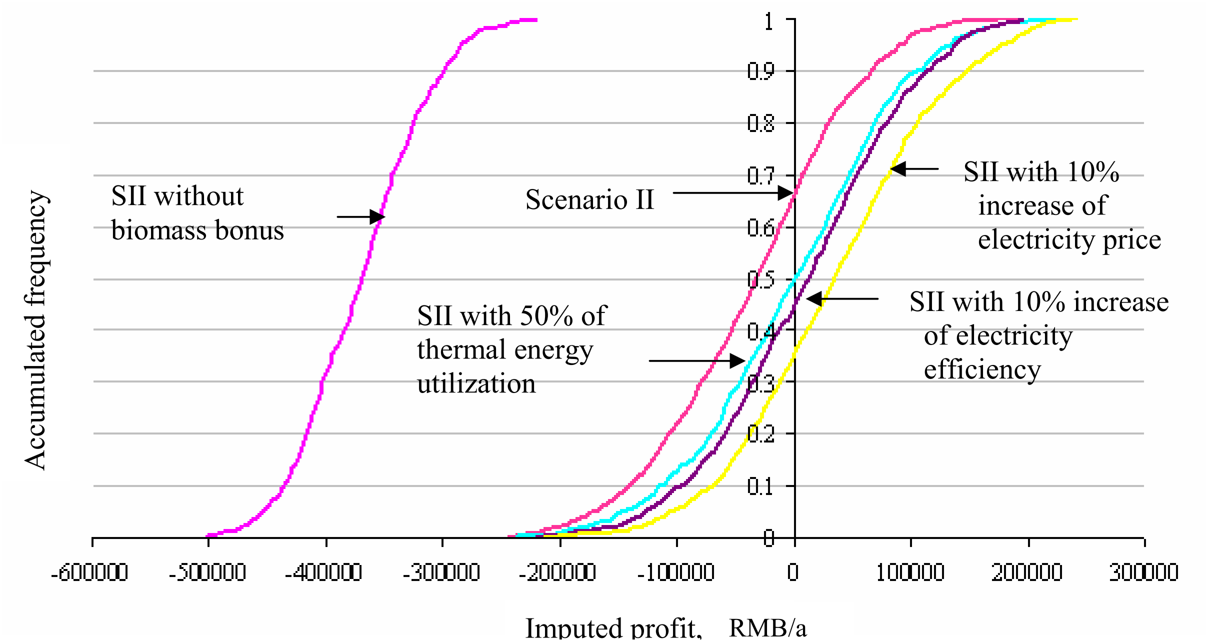


Source: own calculation based on the data from Rauh, 2008

From the distribution function for the Monte-Carlo-Simulation analysis, the annual profit is illustrated to be the difference between -248,000 RMB to 200,000 RMB. The project has a 35% chance of accruing profit. That means the project has 65% risk of gaining profit (see Annex 2).

If one of factors in the costs- revenue evaluation planning were to be changed, the possibility of the project gaining profit would also be changed. This calculation is presented in Annex 2. Figure 34 illustrates the changing nature of imputed profit considering the variation of factors.

Figure 34: Distribution function from effect of some essential factors changing

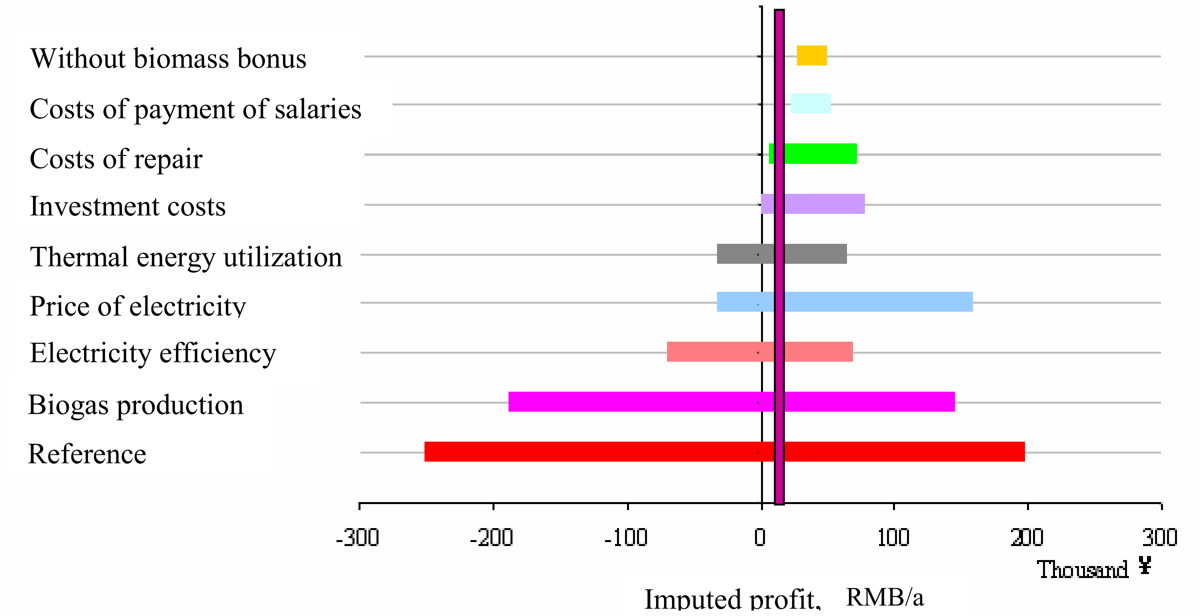


Source: Own calculation based on the data from Rauh, 2008

Figure 34 illustrates the imputed changing nature of profit in relation to essential factors changing. The red curve indicated the Scenario II as shown in the reference case. This is the same as in Figure 33. In this context, profit accrued is considered to be 35%. If the thermal energy utilization were increased by 25% for Scenario II, the annual profit would have been better accrued. Moreover, the possibility for accruing profit could also have increased to about 20%. If the price of electricity had increased by 0.05 RMB/kWh$_{el}$, based on the price of electricity in the reference case (0.33 RMB/kWh$_{el}$), this situation would have been much better than if the thermal energy utilization had increased. In case of 10% electricity efficiency increasing, the possibility for accruing profit could be as much as 65%. But, if the biogas project was designed not for the purpose of feeding into the national grid, the project would have operated without a biomass bonus of 0.25 RMB/kWh$_{el}$. In this context, the project would have been unprofitable (see Annex 2).

Every factor has the possibility of accruing profit. The factors of imputed profit could be carried out using the Monte-Carlo-Simulation. Every factor stands for an imputed band. This is indicated in Annex 2. Figure 35 illustrated the imputed profit band.

Figure 35: Imputed profit band



Source: Own calculation based on the data from Rauh, 2008

Figure 35 shows that the reference case generates imputed profit ranging from -250,000 RMB to 200,000 RMB (see Figure 33). Holding all other factors constant, with exception of the factor for biogas production, the imputed profit is estimated to be a bit less compared with that of reference scenario. Moreover, the project owner also needs to pay attention to the change of electricity efficiency and price of electricity, as well as the thermal energy utilization. In addition, when there happen to be a change in such factors as investment costs, costs of repair, costs of payment of salaries and that without biomass bonus, the project could accrue profit or maintain the balance of profit and loss (see Annex 2).

Thus, the economic analyses are completed for this medium scale biogas electricity project. However, for the investors it is very important to estimate the ecological benefit, as well as carbon dioxide emission reduction benefit.

4.2.3 Ecological analyses

This project is not being registered as a CDM project. Nevertheless, amount of GHG emission can be reduced. Thus, if this project were registered as a CDM project, the investment, technological and barrier due to prevailing practice or others must be explained.

It is easy to understand why the project faces a lack of investment for both scenarios compared to the economic analysed results. Like in Chapter 4.2.2 indicated, the project with Scenario I operates with absolute negative results. In that context, the Scenario II is better. But it also has limited positive profit. In addition, when the project operates with Scenario II, the project will have risks when getting a biomass bonus. Although the project locates in the more developed region of China, but this project get no financial support, neither from government, nor from foreign banks.

Concerning the technological barrier, this biogas electricity project needs advanced technology for manure selection, construction of fermentation, as well as also the electricity production, etc. Moreover, the project owner and workers must have knowledge for project operating and management. Forthermore, there is also no experience from other projects in this location.

Thus, the project results emission reduction. If this project could be a CDM project further, it would bring income to project owner. This chapter will make GHG emission estimation and emission reduction, as well as presenting the costs for emission reduction analysis.

4.2.3.1 Carbon dioxide emission analyses

Before calculating the benefit for the carbon dioxide emission reduction, the amount of energy generated from coal and biogas are the same, but the costs to be paid for the two are different. The costs for the amount of electricity and thermal energy generation must be computed for both biogas production and coal consumption. The price of carbon emission reduction for one kilowatt hour electricity and thermal energy production must be determined for both biogas production and coal consumption.

The carbon dioxide emission reduction can be calculated based on the methodology of the CDM. In that context, the first step is to compute the baseline emission and second step is to determine the project activity emissions (see Chapter 3).

Baseline emissions Considering the baseline scenario calculation, there is no use for electricity and heat. So the carbon dioxide emissions are insignificant and would be considered to be zero. Thus, the baseline emissions are calculated based on the sum of $BE_{CH_4,y}$ and $BE_{N_2O,y}$ coming from emissions of dairy cow waste. The result of BE_y indicates in Table 33.

Table 33: Baseline emissions for Scenario I and II, tCO_{2e}/a

	$BE_{CH_4,y}$	$BE_{N_2O,y}$	BE_y
Scenario I	2,972	802	**3,774**
Scenario II	2,972	802	**3,774**

As Table 33 shows the BE_y are estimated to be 3,774 tons of carbon dioxide for both Scenario I and II (see Annex II-8).

Project emissions For this project, the $PE_{PL,y}$ can be considered as zero (see Chapter 3.2.1). In this case, where biogas is just flared and the pipeline from collection point to flare is short less than one kilometre, and for on site delivery only, one flow meter can be used. Moreover, $PE_{flared,y}$ can also be considered zero. Due to biogas catured being used for power generation, these emissions from flaring of the residue gas stream are not accounted for. The last, $PE_{elec/heat,y}$ can also be estimated to be zero. The reason is the biogas collected is used for power generation and heat energy production. Thus, The project emissions can be calculated by using the formula: $PE_y = PE_{AD,y} + PE_{Aer,y} + PE_{N_2O,y}$. The result indicates in Table 34

Table 34: Project emissions for Scneario I and II, tCO_{2e}/a

	$PE_{AD,y}$	$PE_{Aer,y}$	$PE_{N_2O,y}$	PE_y
Scenario I	77	0.97	94	**172**
Scenario II	385	4.87	468	**858**

The project emissions are calculated to be 172 tCO_{2e} in Scenario I and 858 tCO_{2e} in Scenario II (see Annex II-9).

Leakage emissions The leakage emissions calculation is showed in Table 35

Table 35: Emission leakage, tCO_{2e}/a

	LE_{B,N_2O}	LE_{P,N_2O}	LE_{B,CH_4}	LE_{P,CH_4}	LE_y
Scenario I	64	48	214	137	-93
Scenario II	321	241	1,068	684	-464

In Table 35, the leakage in Scenario I is estimated to be -93 tons and -464 tons carbon dioxide equivalent for Scenario II respectively (see Annex II-10).

<u>*Emission reduction*</u> Emission reduction with the formula $ER_y = BE_y - PE_y - LE_y$ is used for the calculation in the Table 38

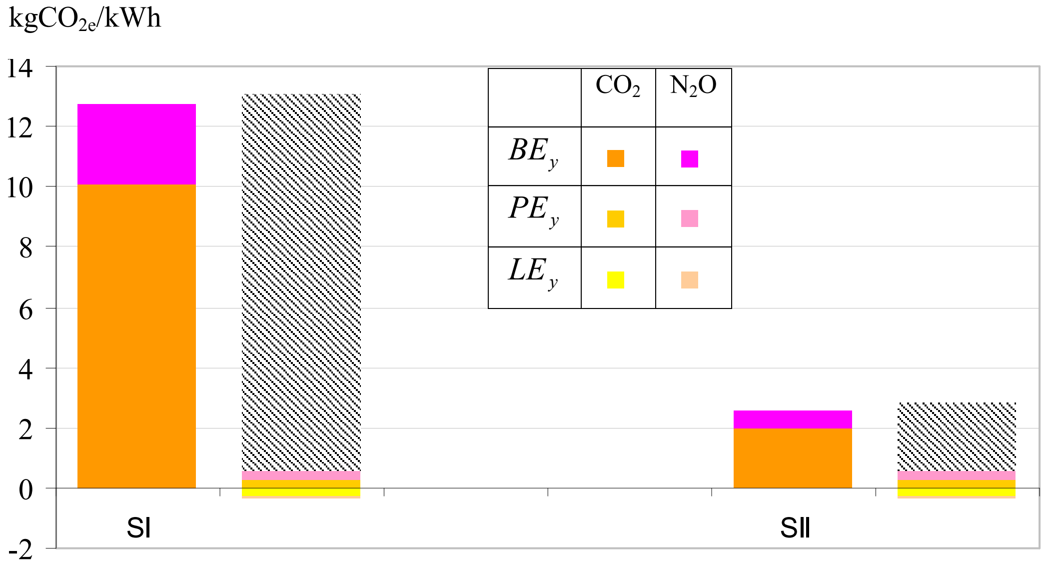
Table 38 Emission reduction in Scenario I and II, tCO_{2e}/a

	BE_y	PE_y	LE_y	ER_y
Scenario I	3,774	172	-93	3,695
Scenario II	3,774	858	-464	3,380

The carbon dioxide emission reduction are estimated to be 3,695 tCO_{2e}/a and 3,380 tCO_{2e}/a for Scenario I and II.

Thus, the BE_y, PE_y and LE_y can also be calculated for electricity production. Figure 36 shows this for both of Scenario I and II

Figure 36: Baseline emissions, project emissions, leakeage emissions and emission reduction for electricity generation concerning Scenario I and II



In Figure 36, for the biogas electricity prodcution project, the emissions produced were greater for Scenario I than for Scenario II. The reason is the same amount of baseline emissions for both scenarios. For project acticity, based on the same amount of animal waste, Scenario I just uses 20% from total waste to produce biogas. In this case, Scenario II operates with 100% waste. So, the emission reduction is also estimated more for Scenario I than Scenario II. However, in this case, the fertilizer utilization is to be considered. Furthermore, scenario I and scenario II are not comparable.

4.2.3.2 Costs of carbon dioxide emissions

The carbon dioxide emissions for both scenarios have already been calculated. Thus, the carbon costs would be estimated. Three steps can be considered here.

First step is to calculate the difference of costs of electricity between biogas production and coal consumption. In this context, two elements need to be considered. The difference in costs for electricity from biogas is the costs of electricity and the revenue of thermal energy from electricity generation. Moreover, the costs of electricity from consumption can be 0.52 RMB/kWh_{th}. This is the costs for electricity consumption for coal for this province.

The second step is the carbon emission reduction between biogas production and coal consumption. In order to calculate the carbon emission reduction from generated biogas, the difference between carbon emissions from electricity generation and from produced thermal energy must be estimated. In terms of carbon emissions from thermal energy production, the thermal energy production from coal consumption can be considered. Thus, the carbon emissions for coal consumption from generated electricity must also be calculated.

The last, the carbon emission reduction costs will follow the same procedure as indicated earlier. This will thus be estimated as the ratio between carbon emission costs for electricity generation and carbon emissions per kilowatt electricity generation for coal consumption and biogas production. Tables 36, 37 and 38 and Tables 39, 40 and 41 are presented the detailed calculations for Scenarios I and II. The calculation for costs of carbon dioxide emissions is indicated in Annex II, volume 8.

Table 36: Difference of costs of electricity between biogas production and coal consumption for Scenario I

Calculated costs of electricity production in biogas project, RMB/kWh_{el}		Costs of electricity of coal consumption, RMB/kWh_{el}
From electricity genearion	From thermal energy revenue	From electricity utilization
1.44	0.044	0.52
Difference		
1.40		
Difference 0.88 RMB/kWh_{el}		

In Table 36, the difference of costs of electricity are estimated as being 0.88 RMB/kWh_{el} in Scenario I.

The carbon dioxide emission reduction between biogas production and coal consumption for Scenario I are indicated in Table 37.

Table 37: CO_2 emission reduction between biogas production and coal consumption for Scenario I

CO_2 emissions in biogas project, t/kWh_{el}		CO_2 emissions from coal consumption, t/kWh_{el}
From electricity production	Thermal energy production from coal consumption	From electricity production
0.00058	0.00011[12]	0.00096[13]
Difference		
0.00047		
Difference -0.00049 t/kWh_{el}		

Table 37 shows the difference in carbon dioxide emission reduction is -0.00049 t/kWh_{el} in Scenario I.

Thus, the carbon dioxide emission reduction costs for Scenario I are showed in Table 38.

Table 38: CO_2 emission reduction costs for Scenario I

Difference costs in CO_2 between biogas production and coal consumption, RMB/kWh_{el}	CO_2 emission reduction between biogas production and coal consumption, t/kWh_{el}
0.88	-0.00049
Relation -1,811	

In Table 38, the emission reduction costs are estimated to be 1,811 RMB/tCO_{2e}.(240 \$/tCO_{2e}) in Scenario I.

---

[12] CO_2 emissions of thermal energy production from coal consumption are equal to CO_2 emissions from coal for heat production of 32 t/a divided by electricity production of 295,650 kWh/a. Here, CO_2 emissions from coal for heat production is equal to coal consumption of 12.12 tons multiplied by emission factor of coal of 0.0026 tons. Moreover, the coal consumption of 12.12 tons is equal to thermal energy production of 98,550 kWh/a multiplied by thermal value of coal of 0.00813 kWh/t.

[13] CO_2 emissions of electricity production from coal consumption are equal to CO_2 emissions from coal for electricity production of 283 t/a divided by electricity production of 295,650 kWh/a. Here, CO_2 emissions from coal for elelctricity production is equal to coal consumption of 106 tons multiplied by emission factor of coal of 0.0026 tons. Moreover, the coal consumption of 106 tons is equal to electricity production of 295,650 kWh/a multiplied by electricity value of coal of 0.00278 kWh/t.

The case for CO_2 emission reduction costs are illustrated in Table 39, 40 and 41.

Table 39: Difference of costs of electricity between biogas production and coal consumption for Scenario II

Calculation costs of electricity production in biogas project, RMB/kWh$_{el}$		Costs of electricity of coal consumption, RMB/kWh$_{el}$
From electricity production	From thermal energy revenue	From electricity production
0.58	0.009	0.52
Difference		
0.571		

Difference
0.051
RMB/kWh$_{el}$

As seen in Table 39, the difference of costs are computed as being 0.051 RMB/kWh$_{el}$ for Scenario II. The carbon dioxide emission reduction between biogas production and coal consumption for Scenario II is showed in Table 40.

Table 40: CO_2 emission reduction between biogas production and coal consumption for Scenario II

CO_2 emission in biogas project, t/kWh$_{el}$		CO_2 emission from coal consumption, t/ t/kWh$_{el}$
From electricity production	Thermal energy production from coal consumption	From electricity production
0.00058	0.00002[14]	0.00096[15]
Difference		
0.00056		

Difference
-0.0004
t/kWh$_{el}$

Thus, the difference of carbon dioxide emission reduction is estimated as being -0.0004 t/kWh$_{el}$. Table 41 indicates the emission reduction costs for Scenario II.

---

[14] CO_2 emissions of thermal energy production from coal consumption are equal to CO_2 emissions from coal for heat production of 32 t/a divided by electricity production of 1,478,250 kWh/a. Here, CO_2 emissions from coal for heat production is equal to coal consumption of 12.12 tons multiplied by emission factor of coal of 0.0026 tons. Moreover, the coal consumption of 12.12 tons is equal to thermal energy production of 98,550 kWh/a multiplied by thermal value of coal of 0.00813 kWh/t.

[15] CO_2 emissions of electricity production from coal consumption are equal to CO_2 emissions from coal for electricity production of 1,414 t/a divided by electricity production of 1,478,250 kWh/a. Here, CO_2 emissions from coal for elelctricity production is equal to coal consumption of 532 tons multiplied by emission factor of coal of 0.0026 tons. Moreover, the coal consumption of 532 tons is equal to electricity production of 1,478,250 kWh/a multiplied by electricity value of coal of 0.00278 kWh/t.

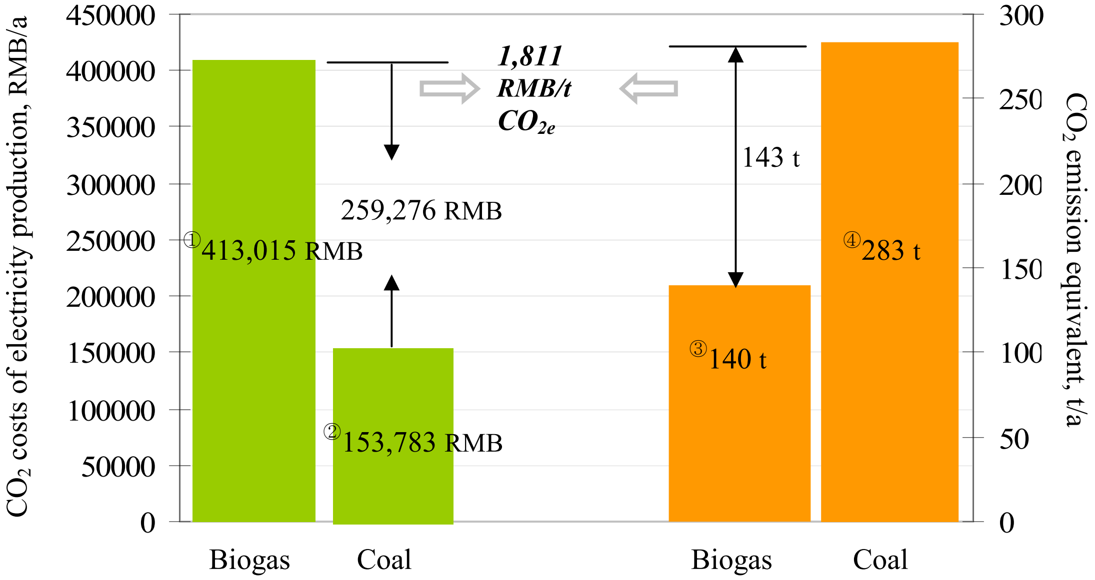
Table 41: CO_2 emission reduction costs for Scenario II

<table>
<tr><th>Costs difference between biogas production and coal consumption, RMB/kWh_{el}</th><th>CO_2 emission reduction between biogas production and coal consumption t/ kWh_{el}</th></tr>
<tr><td>0.051</td><td>-0.0004</td></tr>
<tr><td colspan="2">Relation</td></tr>
<tr><td colspan="2">-127</td></tr>
</table>

In Table 41, in this case, the costs of CO_2 emission reduction are evaluated to be 127 RMB/t (see Table 41).

The result of the amount of CO_2 emission, the costs of emission, and costs of emission reduction for both scenarios is illustrated in Figure 37 and 38 for Scenario I and II.

Figure 37: CO_2 emission reduction in Scenario I



Notes:

① Costs of CO_2 emissions of electricity production are equal to 1.40RMB/kWh of costs of CO_2 for biogas project multiplied by 295,650 kWh of electricity production

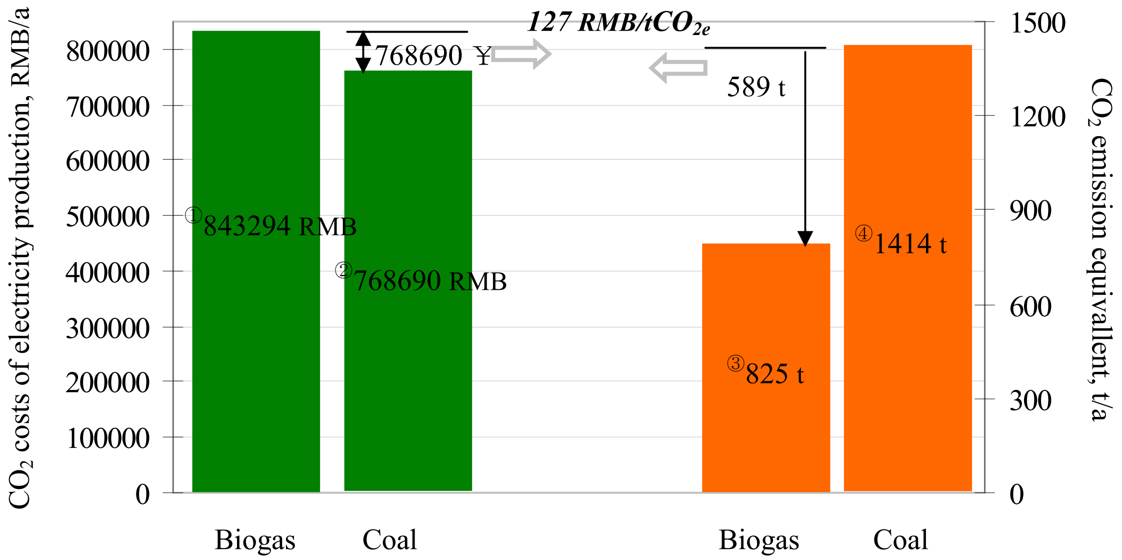
②Costs of CO_2 emissions of electricity production are equal to 0.52 RMB/kWh of costs CO_2 for coal consumption multiplied by 295,650 kWh of electricity production

③CO_{2e} emissions are equal to difference between 172 tons of CO_2 emissions from biogas production and 32 t of CO_2 emission from coal consumption for heat production

④ CO_{2e} emissions are equas to 283 tons of CO_2 emissions from coal consumption for electricit y production

Thus, the Figure 38 shows for Scenario II

Figure 38: CO_2 emission reduction in Scenario II



Notes:

①*Costs of CO_{2e} of electricity production are equal to 0.57RMB/kWh of costs of CO_{2e} for biogas project multiply 1478250 kWh of electricity generation.*

②*Costs of CO_{2e} of electricity production are equal to 0.52 RMB/kWh of costs of CO_{2e} for coal consumption multiplied by 1478250 kWh of electricity generation.*

③ *CO_{2e} emissios are equal to difference between 858 tons of CO_2 emission from biogas production and 32 t of CO_2 emission from coal consumption for heat generation.*

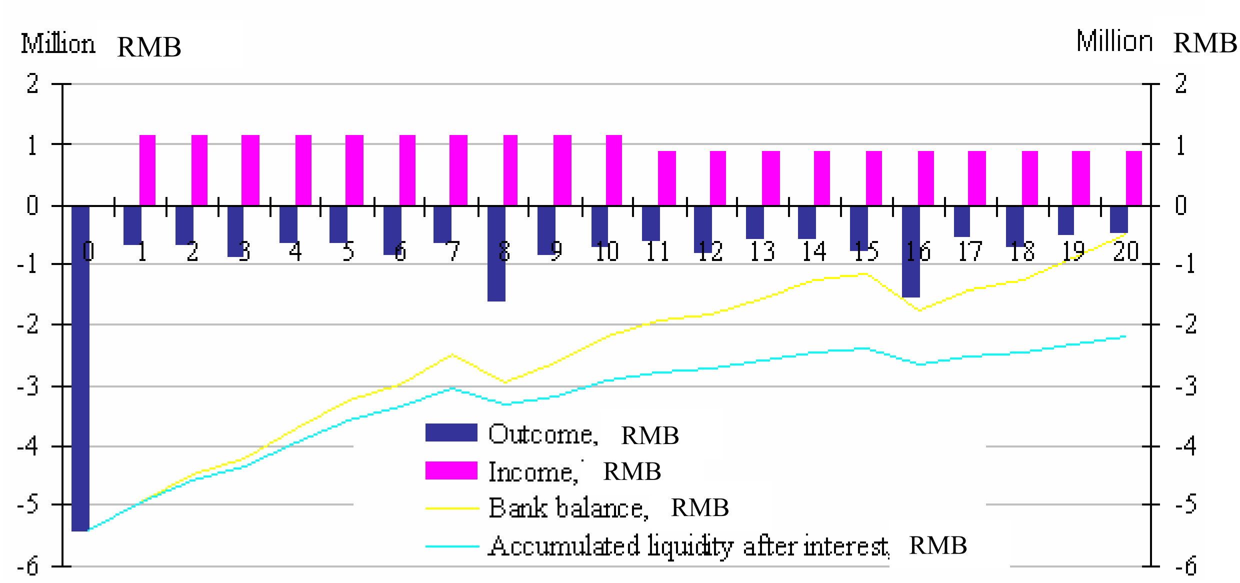
④ *CO_{2e} emissions are equal to 1414 tons of CO_{2e} emission from coal consumption for electricity generation.*

4.2.3.3 Cash flow and liquidity (with CERs)

Considering the result of total costs, revenue and also possible income from carbon trading for both project scenarios I and II, the cash flow and liquidity can be also analysed. Moreover, the financial analysis will be made considering the current price of carbon on the market for both scenarios of project income. In the case carbon revenue from CDM can be added to that of the project, the CDM preparation costs must also be added to the project outcome. That needs to be divided by 20 years which denoted the lifetime of the project. Currently, the CDM preparation costs for both scenarios can be considered to be more than US$ 100 thousand. In the worst case, this preparation costs will also be between US$ 200 thousand and US$ 250 million, depending on the project size. Thus, the outcome consists of costs of repair, costs of insurance, costs of payment of salaries, energy costs for processing, and other unforeseeable costs and also the base rate for a bank loan. The income- revenue from electricity generation, thermal energy generation and revenue from carbon trading considering the current carbon market price of 10 \$/t CO_{2e} (75 RMB/tCO_{2e}). In this context, the liquidity for Scenario II is indicated, which could be made from the current price of carbon. These calculations are indicated in Annex 2. Here, due to the very unprotability of Scenario I, the liquidity for this scenario will be not considered.

Thus, in Scenario II. The total investment costs are separated into two parts. There are the costs for biogas project and CDM preparation costs. Moreover, the context for Scenario II can be understood by taking a closer look at that Figure 39.

Figure 39 Financial liquidity with the equivalent carbon price of 10 \$/tCO_{2e} and minimum CDM preparation costs for Scenario II



In Figure 39, the investment costs are evaluated to be 5.4 million RMB, from which the personal contribution is estimated to be 2.4 RMBplus 0.05 million \$ (0.375 million RMB) half of which coverd CDM preparation costs. The rest is considered to be a bank loan. The outcome is computed between 0.45 million RMB to 0.66 million RMBannually. The income is estimated to be 1.12 million RMB annually. Despite the fact that the annual income is exceeded the outcome, the project operated under the condition of Scenario II is still unprofitable (see Annex 2). However, the situation is much better than that of Scenario I. In that context, both scenarios I and II are unprofitable when they are considered as CDM projects with the price of carbon trading being 10 \$/t CO_{2e}.

Thus, the economic and ecological analyses are completed for this project. For this medium scale farm, the situation is absolutly unprofitable for Scenario I. In this case, the income from fertilizer production is neglected. In the case of Scenario II, the project owner can accrue a very limited profit. Moreover, the financial situation considering the operating lifespan appears negative, even in the case of a CDM project. However, the ecological benefit is obvious, especially for GHG emission reduction. As indicated earlier, there are many larger biogas electricity projects in China, for which the generated electricity is meant for sale and for feeding into the national grid. The economic and ecological analyses for large scale biogas electricity project will be made in the next section.

4.3 Economic and ecological aspects of a large scale chicken farm biogas electricity generation project

The presented biogas project is a key project in China. This is a large scale chicken farm with abounded waste. The project intended to produce biogas electricity to be fed into the national grid. In addition, the project has applied for a CDM project. Thus, this chapter will present the economic and ecological analyses for this large biogas electricity generation project.

4.3.1 Project background

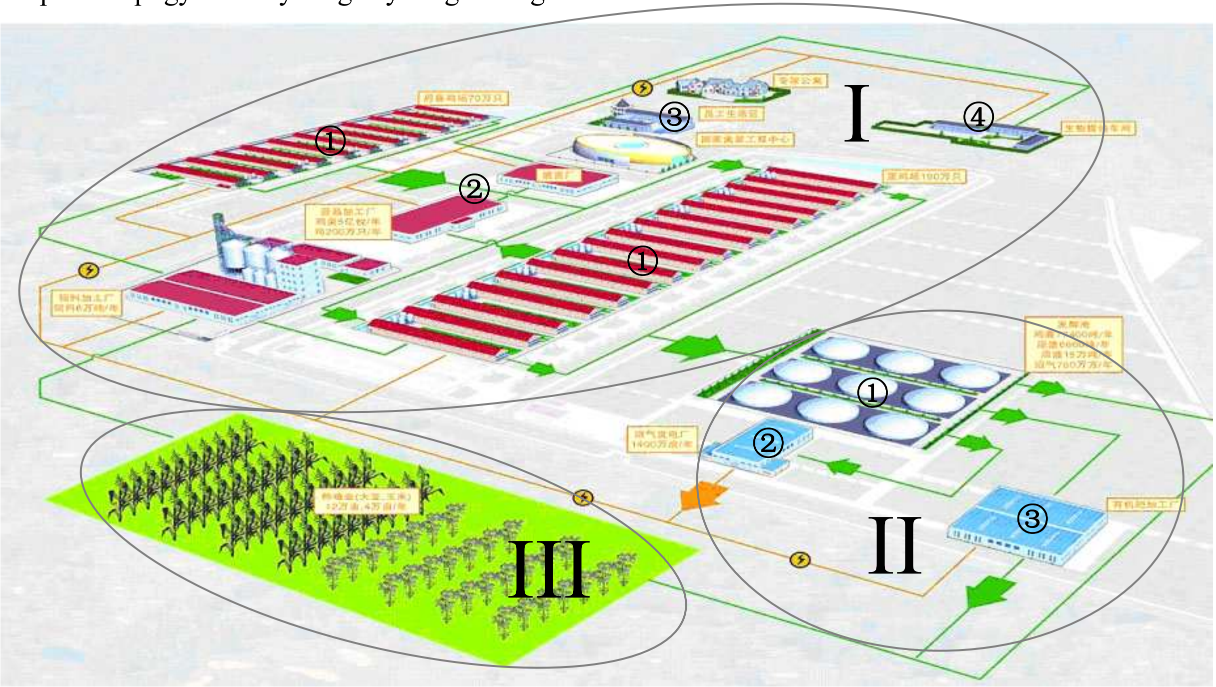
Deqingyuan farm is located in Beijing Yan Qing County, which has 2,500 thousand layers and 500 thousand pheasants. Deqingyuan is a large chicken egg producer; the total amount of production provide for about 25 percent of the egg consumption in Beijing's market. At the same time, the chicken waste produced approx 212 tons plus 318 tons waste water are discharged on a daily basis (MOA, 2006b). The geographic location is indicated in Map 4.

Map 4: Geographic location of Deqingyuan farm

Source: MOA, 2008

The Deqingyuan biogas electricity generation project proposal is also from MOA. In view of that, the Deqingyuan biogas project operates under the condition of the "cycling ecological-economics" model. For Deqingyuan farm, due to the total amount of more than 3,000,000 egg-laying chickens, plenty of waste is produced. Deqingyuan farm can be divided up into three parts. The first part is the industrial area. In this area, the farm consists of a food factory which produce liquid egg, egg powder, fodder process, as well as of a quality control centre. Moreover, there are some building for staff accommodation. The second part of Deqingyuan farm is the biogas electricity generation project. This section includes the biogas anaerobic digestion system, CHPP, as well as a fertilizer production plant. The third part is a arble land orchards. Map 5 indicated the Deqingyuan "cycling ecological-economics" farm.

Map 5: Deqingyuan recycling "cycling ecological-economics" model



Source: MOA, 2008

Notes:
I ①Chicken farm ②Food factory ③Staff living ④Food control centre
II ①Biogas anaerobic digestion ②CHPP ③Fertilizer production
III Cropland

Thus, the first part plays the role of the original waste producer, as well as that of the "user" of the produced energy. The chicken waste and waste from the food factory and the living area can be exploted as biomass for biogas production. The second part is the biogas electricity generation project, for which the economic and ecological analyses will be performed. In this context, the fertilizer production and utilization thereof can also derive more benefits directly resulting from the project. The reason is that the organic fertilizer produced can be applied to cropland and orchards located near the project area. This can substitute chemical fertilizer utilization, as well as deal with the problem of large mount of biogas residue. The project economic benefit is limited to the biogas electricity generation project, but considering the entire project, the project owner can obtain annual profit from egg production, cropland and orchards. In addition, the ecological benefit can also be seen to lead to a reduction in carbon dioxide emissions. This is one of the reasons why this project is a high status national project. With the different specific project context for biogas electricity generation, the "eco-farm" model can also be implemented anywhere in rural areas in China.

The economic and ecological analyses for this biogas electricity project will be made in this section (see Map 5). The Deqingyuan farm constructes a biogas plant to dispose the waste. Due to the large amount of waste production, the biogas could also produce large amount energy. Thus, some farm data are introduced in Table 42.

Table 42: Description of the study model farm

Animal stock:	Value
Pheasant (thousand)	500
Layer chicken (thousand)	2,500
Production:	
Eggs (annual, million)	500
Liquid eggs and egg powder (thousand tons)	10
Manure management:	
System	Open lagoon storage
Waste amounts (per day)	waste 212 tons, waste water 318 tons

Source: MOA, 2006b

The biogas project needs 33,300 m^3 in terms of land area. With the daily 212 tons of chicken waste and 318 tons of waste water, the daily biogas can be estimated to be 19,000 m^3 with the chicken waste dry matter constituting 30%. Thus, the annual biogas production is evaluated to amount to 7 million m^3. In order to construct a biogas electricity generation project, the investment costs must be very well arranged. The total investment costs are calculated from the initial civil engineering costs, equipment investment and other costs as listed in Annex III-1,2 and 3. Thus, the total investment costs are estimated to be 48.29 million RMB, of which 5.54 million RMB for construction and 36.51 million RMBfor equipment costs (see Annex III-1,2 and 3).

With the total investment costs of 48.29 million RMB, the annual costs, revenue and profit/loss can be calculated for the project duration. It must be noted, that the CHPPs are imported from Austria GE Jenbacher which included 2 units of 1,064 kW of installed electricity capacity. The Shandong Shengdong CHPPs are also considered for this project with 5 units of 420 kW electricity capacity installed. The difference between GE Jenbacher and Shandong Shengdong CHPPs is illustrated in Table 43.

Table 43: CHPP parameters from Jenbacher and Shengdong

	Units	Installed capacity, kW	Electricity capacity, %	Thermal capacity, %	Total capacity, %	Maintenance period, h	Lifetime period, h
Jenbacher J320	2	1,064	38.5	42.5	81	8,000	60,000
Shengdong 500GFI-RZ	5	420	30.8	39.1	69.9	8,000	20,000

Source: MOA, 2006b

Thus,. for this project, there are 2 units of 1,064 kW for Jenbacher or 5 units of 420 units for Shengdong CHPPs proposed. The electricity efficiency of Jenbacher is 8% higher than Shengdong's and the thermal efficiency is 3% higher. Both types of CHPPs neede to be changed after 8,000 hours. The motor needs to be changed after 60,000 hours for Jenbacher and 20,000 hours for Shengdong. This can be regarded as the amortization costs of CHPP which for Shengdong are much higher than Jenbacher. There are also large differences between costs of CHPPs, derived from the information from the project design document by MOA and from the sale information in Shengdong Company itself. The costs of Jenbacher CHPP for a capacity of 1,064 kW are 7,800 thousand RMB and 1,100 thousand RMB for 420 kW capacity for Shengdong CHPP. In this cotext for this project, 15.6 million RMB are required for Jenbacher's CHPP in constrast to 5.5 million RMB needed for Shengdong's CHPP for this project.

After the introduction of the project background, the economic and ecological analyses will be made for this project in the following section .

4.3.2 Economic analyses

With references to the methodologies described in Chapter 3, the economic and ecological analyses will be made for a large biogas electricity generation project. For this project analyses, two scenarios which use CHPP will be compared with the technology from both Austria and China. Moreover, the different electricity and thermal energy production result from the different the amount of GHG production. Thus, the ecological analyses will be completed for both these scenarios.

4.3.2.1 Cost-revenue analysis

There are two scenarios proposed for the economic estimation of this project. The first, the project activity with Jenbacher's CHPP and the second- with Shengdong's CHPP. Thus, for the calculation, the costs evaluation should be made, then, the sensitivity analysis, break-even point estimation, the "worst", "normal" and "best" cases evaluation, the project liquidity and CO_2 performance costs must all be carried out for both scenarios.

So, the costs evaluation must be calculated on the basis of the annual project costs and revenue, with the total investment costs of 48.29 million RMB for the first scenario, of which 23.50 million RMB can be proposed as the firm's own capital and the remaining costs are financially supported by Beijing project government. In the second scenario, the total investment costs can be estimated at 38.19 million RMB, of which only 13.40 million RMB are supported by the Beijing government. The operating costs for both scenarios will include interest, amortization, repair, insurance, salary, process energy costs and other costs (see Chapter 3.1). The interest charges can be calculated from the 5.76% of loan deposited. The amortization costs will be calculated within 20 years of the equipment construction life-time and 8 to 10 years for equipment depending on the equipment types. With a life-time of 60,000 hours for Jenbacher's CHPP and 20,000 hours for Shengdong's CHPP, the costs of repair are estimated to be 1.5% of the investment costs. Moreover, 16 members of staff shall be needed for the project. The process energy costs and other costs must also be evaluated to assess the total annual costs. In Table 44 the annual costs of evaluation for both Scenarios I and II are presented.

Table 44: Annual costs calculation with the Jenbacher's and Shengdong's CHPPs

Conponents, RMB/a	Value	
	Scenario I	Scenario II
Interest charges 5.76% of investment costs	1,727,892	1,366,532
Amortization 20 years of equipment construction; 8, 10 years of equipments	4,873,475	4,023,475
Costs of repair 1.5% of investment costs	724,418	572,918
Costs of insurance 0.5% of investment costs	241,473	190,973
Costs of payment of salaries	480,000	480,000
Process energy costs	599,907	479,926
Other costs	965,891	763,891
Total annual imputed costs	9,613,056	7,877,715

Note:
The investment costs were estimated to be 48,294,553 RMB for Scenario I and 38,194,553 RMB for Scenario II

In Table 44, it can be seen that the investment costs are 48.29 million RMB for Scenario I, and 38.19 million RMB for Scenario II. For both scenarios, the amortization costs and interest charges are the greatest costs. Moreover, not only the other costs must also be considered, but also the repair costs. In addition, the process energy costs and costs of salary payment will also entail charges for the project owner, including the costs of insurance. Thus, the annual costs are estimated to be 9.6 million RMB for Scenario I and 7.88 million RMB for Scenario II.

After annual imputed costs evaluation for both scenarios, the revenue also needs to be calculated. Thus, for both scenarios, the revenue can be divided into tow parts- the electricity and heat production. In view of this, the electricity needs to be sold to the national power grid, and the heat generated and utilized by local company. The electricity efficiency is estimated to be 38.5% for Scenario I and 30.8% for Scenario II, and the thermal efficiency is 42.5% and 39.1% (see Table 43). The average of price of electricity for feeding the national grid in Beijing is 0.38 RMB per kilowatt hour and the 0.25 RMB as biomass bonus per kilowatt hour. The price for thermal energy consumption is the same as that for the thermal energy consumption of coal. The annual revenue for Scenario I and II is indicated in Table 45.

Table 45: Annual electricity and heat production, revenue calculation for Scenario I and II

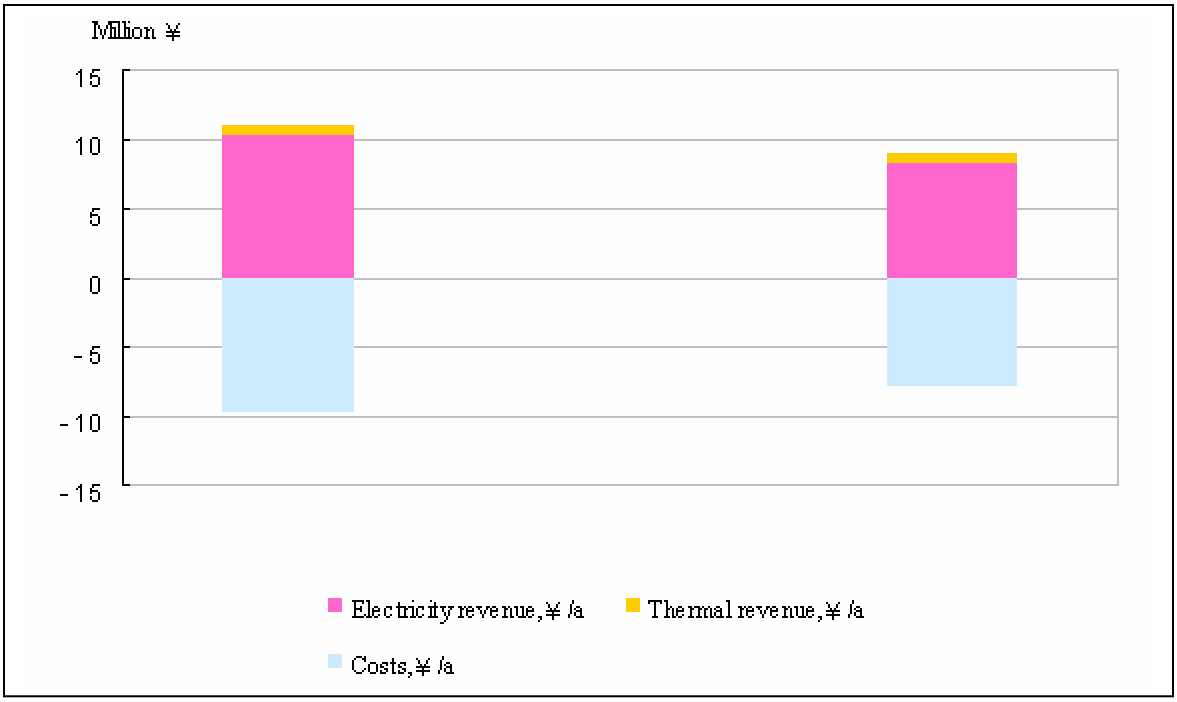
Data	Unit	Value	
		Scenario I	Scenario II
Net electricity energy	kWh$_{el}$/a	16,170,000	12,936,000
Net heat energy	kWh$_{th}$/a	6,247,500	5,747,700
Electricity price	RMB/kWh$_{el}$	0.38	0.38
Renewable energy bonus	RMB/kWh$_{el}$	0.25	0.25
Coal price	RMB/t	1,080	1,080
Energy content of coal	kWh/t	8,130	8,130
Heat price	RMB/ kWh$_{th}$	0.133	0.133
Annually revenue		In RMB	In RMB
The sale of electrical energy		10,196,802	8,157,441
Heat utilized by local company		829,212	762,875
Heat selling		0	0
Total revenue	RMB/a	11,026,014	8,920,316

Thus, in Table 45, there are different amount of electricity and thermal energy production between both scenarios, due to the different electricial and thermal energy efficiencies. Althrough the prices for electricity and thermal energy are the same for both scenarios, the annual revenue for Scenario I is greater for Scenario II. As a result, the project with Scenario I can accrue profit of 1.41 RMB a opposed to Scenario II with a profit of 1.04 million RMB annually.

The result for the comparison between Scenario I and Scenario II is illustrated in Figure 40.

Figure 40: Annual costs, revenue and profit for Scenario I and II

RMB



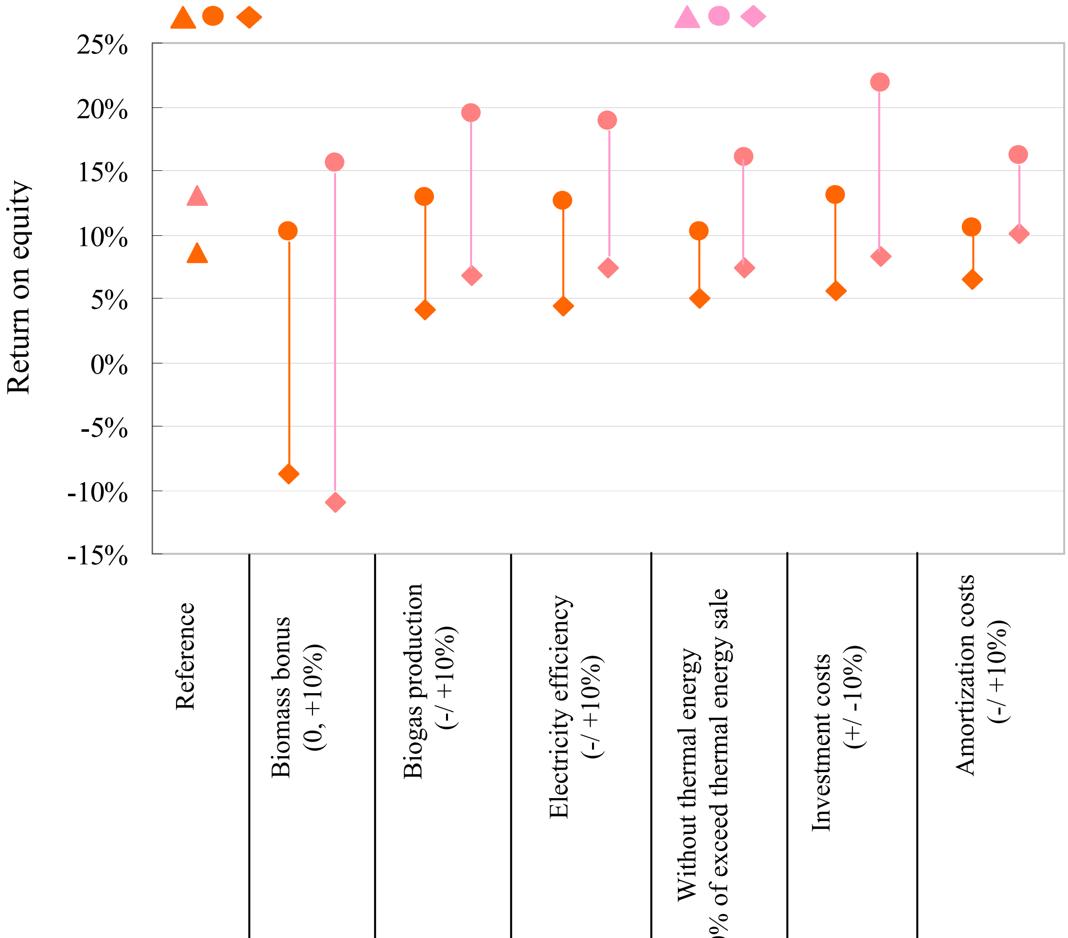
Scenario I and II illustrate the comparison between the project with CHPP of Jenbacher and that with Shengdong. As seen in Scenario I, with the higher costs, the revenue are also higher. Both scenarios accrued profit with the difference in the amount of profit earned being 370 thousand RMB annually. After the cost-revenue analysis, next, the sensitivity analysis will be made for both scenarios.

4.3.2.2 Sensitivity analysis

For sensitivity analysis. the following factors: biomass bonus, biogas production, electricity efficiency, thermal energy utilization, investment costs and the lifetime of equipment must be taken into consideration. Moreover, it seems that the project can be better operated with Scenario I than with Scenario II, but Scenario I needs a larger bank loan compared with that required for Scenario II. This is the reason why the sensitivity analysis can be made for the return rate of investment (see Annex III-4). In Figure 41 this sensitivity analysis is shown.

Figure 41: Sensitivity analysis of return on equity for Scenario I and II

Scenario I   Scenario II



After the sensitivity analysis of return on equity for both scenarios, the situation can be considered better for Scenario II than for Scenario I. Thus, both scenarios operate unprofitably, when the project does not obtain a bonus. In the case of a 10% increase in the bonus, the project could accure slightly more profit than in reference scenarios. Furthermore, the factors involving biogas production and electricity efficiency show a similar outcome. Moreover, these factors are sensitive in both scenarios. In addition, the other three factors have also have more or less influence on the project.

The sensitivity analysis shows which factors may have a greater effect on project operation. In the event that some factors run badly, the project may suffer drawbacks. The project owner also needs to understand the balance between profit and loss. The next part will present the break-even analysis of the project.

4.3.2.3 Break-even analysis

The Break-even point analysis will also be carried out for economic evaluation. The Break-even point indicates the balance of profit and loss. Here, the costs will be computed from 0%

to 100% concerning the electricity production capacity utilization considering the time frame from 0 hours to 7500 hours. The Break-even analysis is indicated in Annex III-5 and 6 for Scenario I and II. Figure 42 and 43 illustrate the Break-even point analysis for both Scenarios.

Figure 42: Break-even analysis for Scenario I

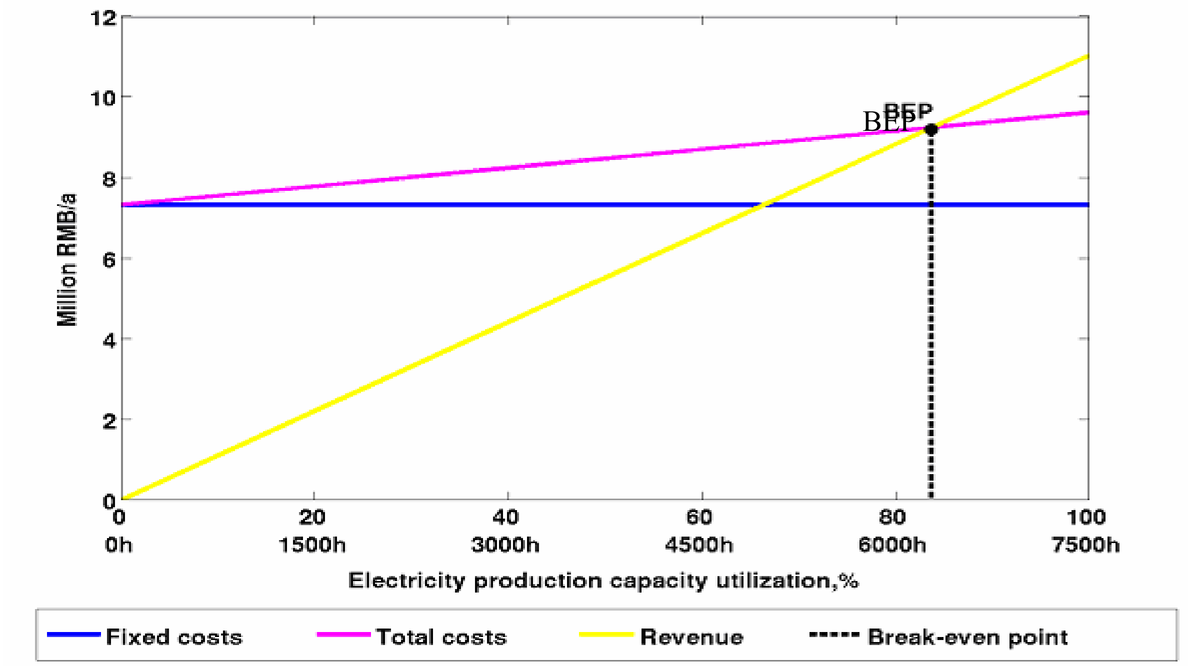
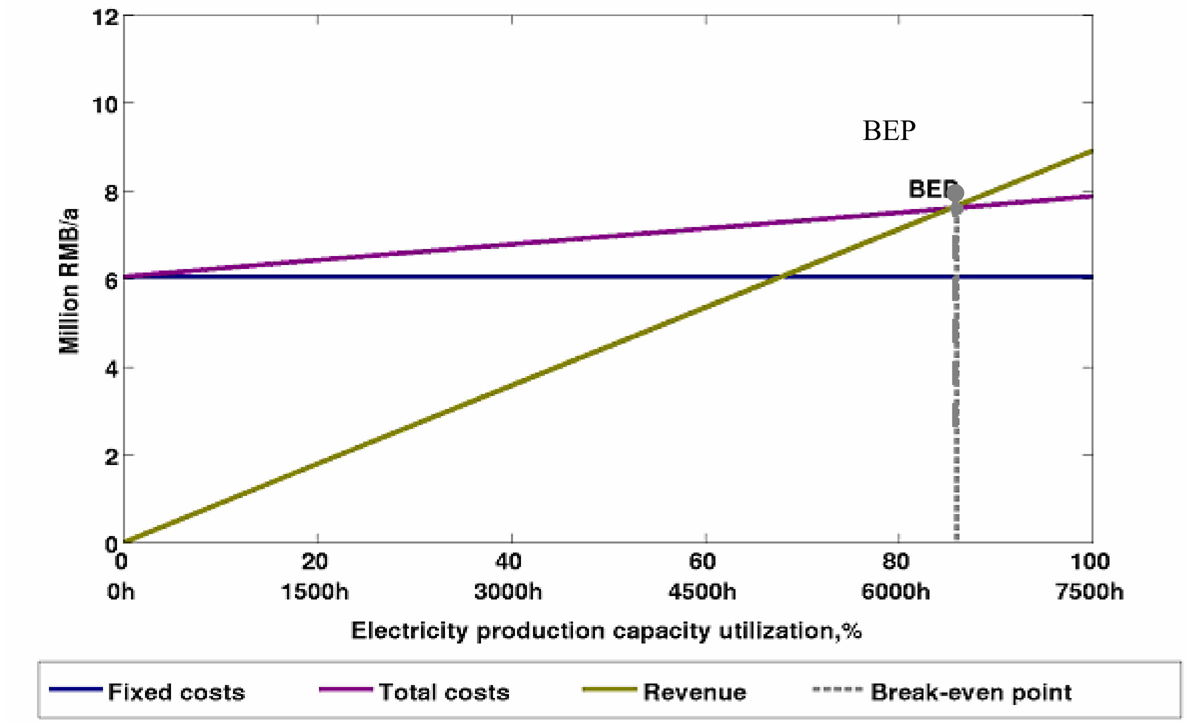


Figure 43 illustrates the break-even analysis for Scenario II

Figure 43: Break-even analysis for Scenario II

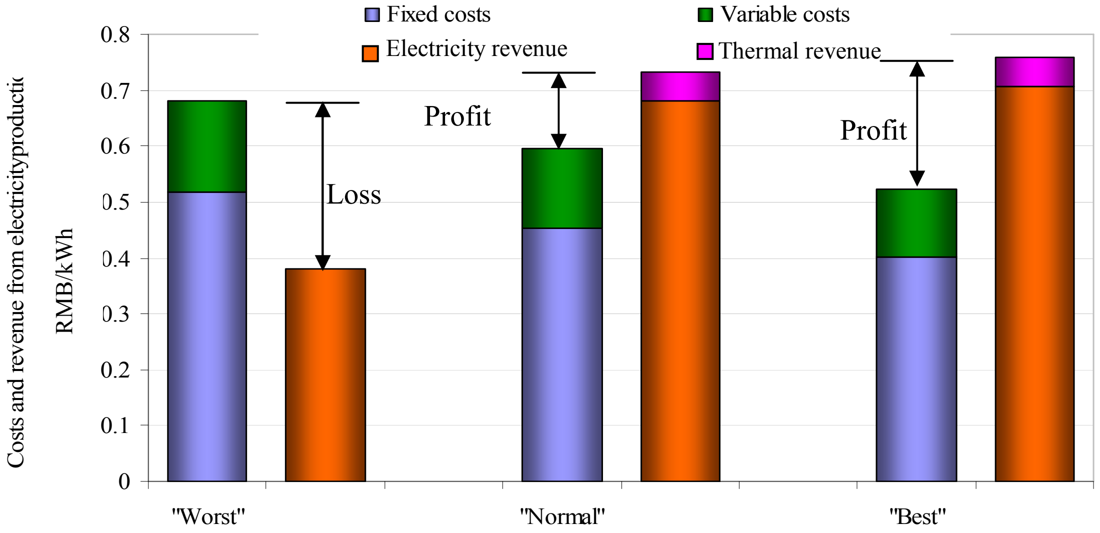


For both scenarios, the fixed costs here include interest, amortization, costs of insurance and salary. The total costs are the sum of fixed costs and variable costs. These costs trends concern the electricity production capacity utilization from 0% to 100%. Thus, the break-even points are 86% and 87% for Scenario I and II. The right side of the break-even point, the distance between the two lines of total costs and revenue are considered the project profit area whilst the project loss area would be that regarded from the left side of break-even point between the lines of total costs and revenue's area. In the case of project well operating, the project may accure more profit and, if some factors were to have an adverse effect, the result could be more serious. Futhermore, if most factors DO not operate well, the project must face the worse case. In this context, when most of the factors run better than normal case, the project owner may accure more profit. Thus, the analyses for the "worst", the "normal" and the "best" cases are shown in Chapter 4.3.2.4.

4.3.2.4 The"Worst", "normal" and "best" cases analyses

After sensitivity and break-even analyses, however, the project operated would be more interesting for investors. In this case, the "worst", "normal" and "best" cases can be made for both scenarios. The "worst" case means for all factors in the worst situation. In view of this, the investment costs can be increased by 10%, and the project can operate with a 10% decrease in biogas production. In the case of no biomass bonus, the project will have absolute loss. Moreover, the thermal energy cannot be used in the summer. The normal case can be regarded as reference situation, and the best case can occur when all the factors are in the best situation. In terms of best case, investment costs will decrease by 10% and the biogas production will increase by 10% compared with those in the reference scenario. Moreover, the biomass bonus can also be increase further, and it can estimated at 10% higher than current price. Furthermore, the fixed and variable costs must be calculated for three case studies. The content of these two costs are introduced in break-even analysis (see Chapter 3.1.3.). Thus, this calculation for three cases is indicated in Annex III-7 and 8. Figure 44 and 45 present the "worst", "normal" and "best" case for both scenarios.

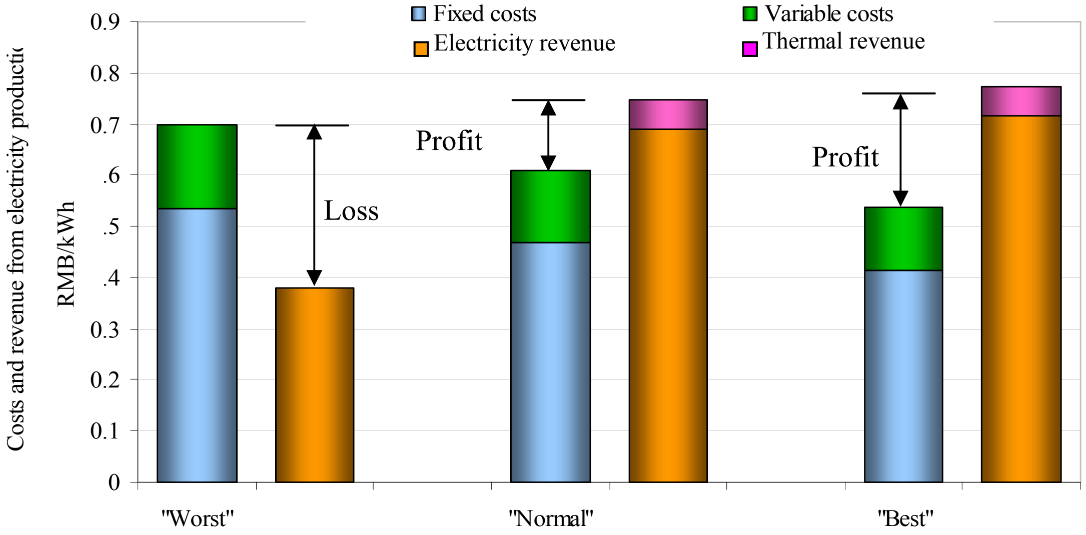
Figure 44: The “Worst”, “normal” and “best” cases for Scenario I



Indicated in Figure 44, for the worst case for Scenario I, the fixed costs for each kilowatt electricity generation are estimated to be 0.06 RMB, more than that in reference scenario. The reason is a 10% investment costs increase in worst case. The revenue can be accured only from electricity production and without accruing a bonus. Due to the small amount of revenue from generated electricity, the revenue in the worst case is estimated to be 0.35 RMB per kilowatt hour lower than that in the normal case. Thus, in the worst case, the loss is estimated to be 0.31 RMB for each kilowatt electricity generation. If the project operates with the normal case, which has already been shown in the cost-revenue analysis, then the profit of generated electricity is computed to be 0.13 RMB per kilowatt hour. For the best case, involving a 10% higher biogas production plus a biomass bonus, as well as having 10% lower investment costs, the project can then accure more profit. The total sum of profit would be 0.25 RMB per kilowatt hour electricity production.

Concerning the three cases analysis for Scenario I, the “worst”, “normal” and “best” case study for Scenario II also indicates the same situation, which is illustrated in Figure 45.

Figure 45: The “Worst”, “normal” and “best” cases for Scenario II



The Figure 45 presents the worst, normal and best cases for Scenario II. Concerning the worst case, the costs of generated electricity are computed to be 0.09 RMB per kilowatt hour whilet that for revenue stands at 0.31 RMB per kilowatt hour lower than that compared with normal case. Considering the best case, the kilowatt hour generated electricity costs are estimated to be 0.05 RMB lower that of the revenue 0.03 RMB higher.

Thus, after the cost-revenue, sensitivity, break-even and three cases analyses, the project cash flow and liquidity will be presented in Chapter 4.3.2.5 concerning the study procedure.

4.3.2.5 Cash flow and liquidity

After sensitivity, break-even, the “worst”, “normal” and “best” cases evaluation, the liquidity analysis should also be interesting for project operation. Thus, the income, outcome must be calculated for 20 years which is expected to be the project lifetime. The income includes electricity and thermal revenue. The outcome can be separated from annual costs excluding interest charges, and the costs for equipment during their lifetime. Moreover, the bank balance and accumulated liquidity would also be made to show the financial situation for both scenarios (see Annex 3). Figure 46 and 47 illustrated the liquidity situation for Scenario I and II.

Figure 46: Cash flow and liquidity analysis for Scenario I

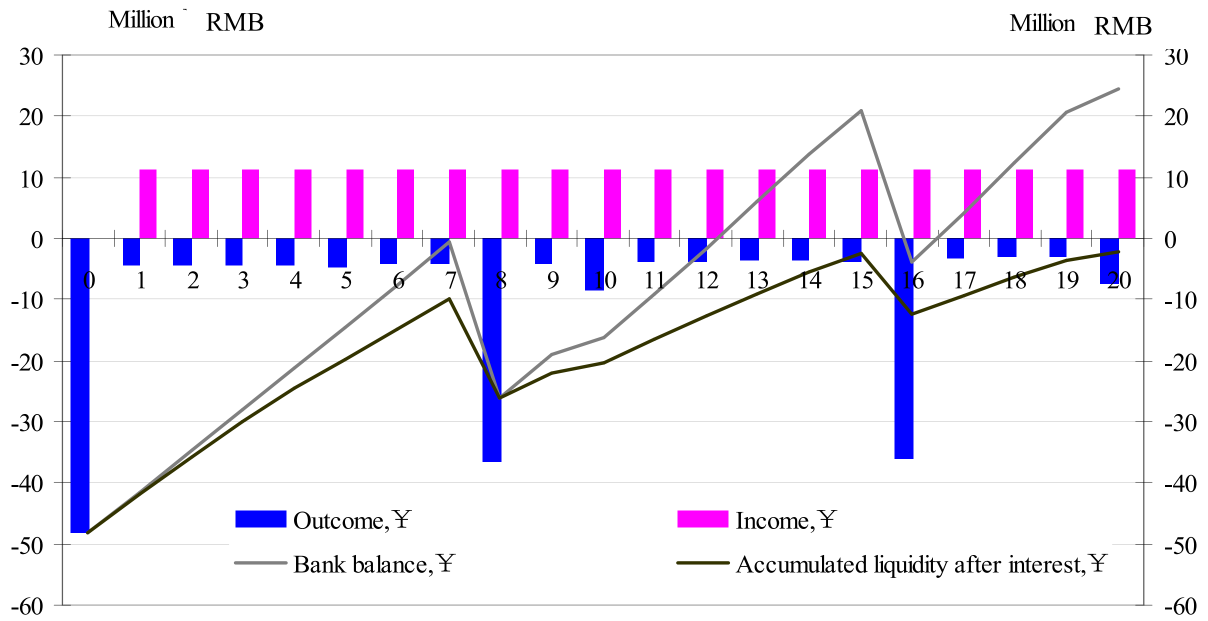


Figure 46 illustrates the liquidity situation for Scenario I. At the beginning of project operation, the total investment costs are calculated to be 48.29 million RMB. The outcome must be considered as the some equipment must be replaced. In this context, in every fifth year, the biogas flowmeter and reactor detector must be replaced. Moreover, most of the equipment, like the equipment for the anaerobic digester, for biogas residue's electrical equipment must also be completely renewed every eighth year. In addition, the Jenbacher CHPP must be fitted with a new motor for every eight year. Except for the years of eight and sixteen, the income is computed more than outcome. However, the cash flow is evaluated and summarized for every year's income and outcome, the cash flow before and after interest should also be calculated. Thus, the bank balance is estimated with the accumulated yearly income and outcome from the beginning of the year of investment, till the last year (the 20th years). The bank balance is 24.5 million RMB, but if the present value of each years cash flow is considered, the accumulated liquidity for project is estimated to be -2.30 million RMB, which could make the project unprofitable (see Annex 3).

The cash flow and liquidity for Scenario II indicated in Figure 47 below.

Figure 47: Cash flow and liquidity analysis for Scenario II

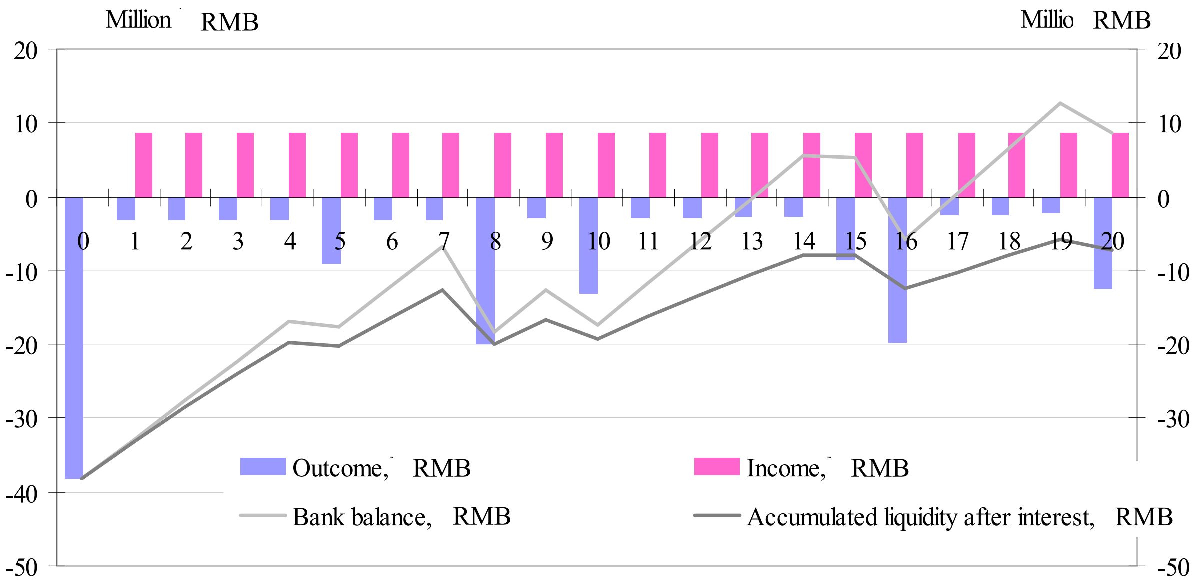


Figure 47 indicated the financial situation of the project for Scenario II, the total investment costs are 38.19 million RMB. The outcome is the annual costs without amortization costs. However, in every fifth and eight year, the costs have to be paid for equipment replacement. In this context, the CHPP for Shengdong stated should also be paid every fifth year for the complete change of equipment. The income is less than outcome for some years, when equipment change takes place.

Thus, the cash flow and liquidity are also calculated for the financial situation of this project , and the bank balance with the present value had been computed to be under zero for the fifth year, eighth year, tenth year, fifteen year, sixth year and twentieth year. The accumulated liquidity after interest have been calculated to be less than zero and it had been estimated to reach -7.10 million RMB in the twentieth year. Thus, the cash flow and liquidity reveal both scenarios to be unprofitable (see Annex 3).

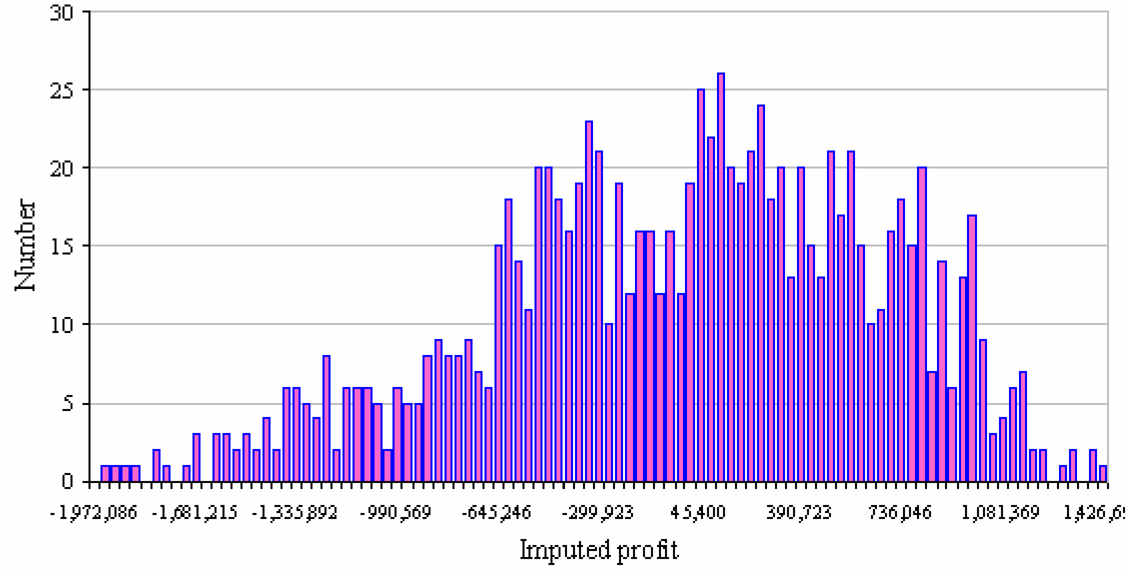
Thus, both scenarios are proven to be unprofitable. In this context, it is very important to make the risk analysis for the project, in order to find the factors with the greatest influence. The next section will present the analysis for Monte-Carlo-Simulation.

4.3.2.6 Monte-Carlo-Simulation

According to the economic evaluation procedure, the Monte-Carlo-Simulation must be carried out for project risk analysis. As regards the Monte-Carlo-Simulation, the input data will be made for every factor in costs evaluation, for example, for investment costs, energy production, electricity revenue, etc (see Chapter 3.1.6).

Both scenarios' risk analyses could be made and explained as density function and distribution function. From the right side of above result, the project profit density function for Scenario I and II is indicated in Figures 48 and 49. The calculation for the Monte-Carlo-Simulation is depicted in Annex 3 for both Scenario I and II. The density and distribution function are also shown in Annex 3, for Scenario II.

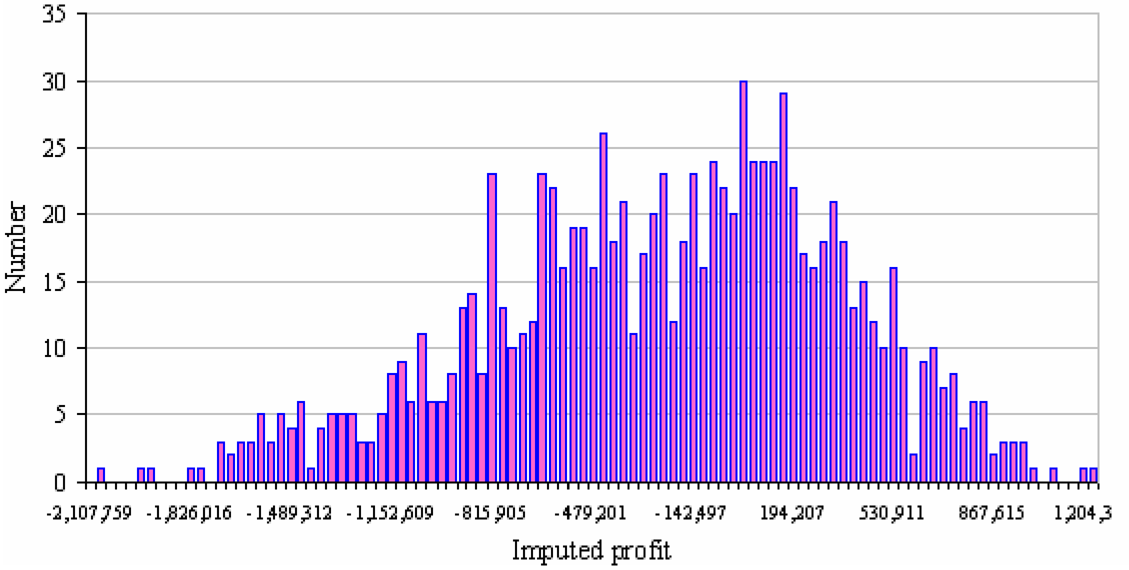
Figure 48: Density function of Scenario I



Source: Own representation based on the data from Rauh, 2008

For Scenario I, the project can a greater chance to operate with profit accruing between -645 thousand RMB and -300 thousand RMB, between 50 thousand RMB and 390 thousand RMB. The project might also have a greater chance to operate with profit accruing between 500 thousand RMB and 1 million RMB. Thus, the project has the chance of yielding profit rather than a loss. And the project's maximum loss amounts to about -2 million RMB and the maximum profit – 1.4 million RMB. The density function for project with Scenario II is illustrated in Figure 49.

Figure 49: Density function of Scenario II

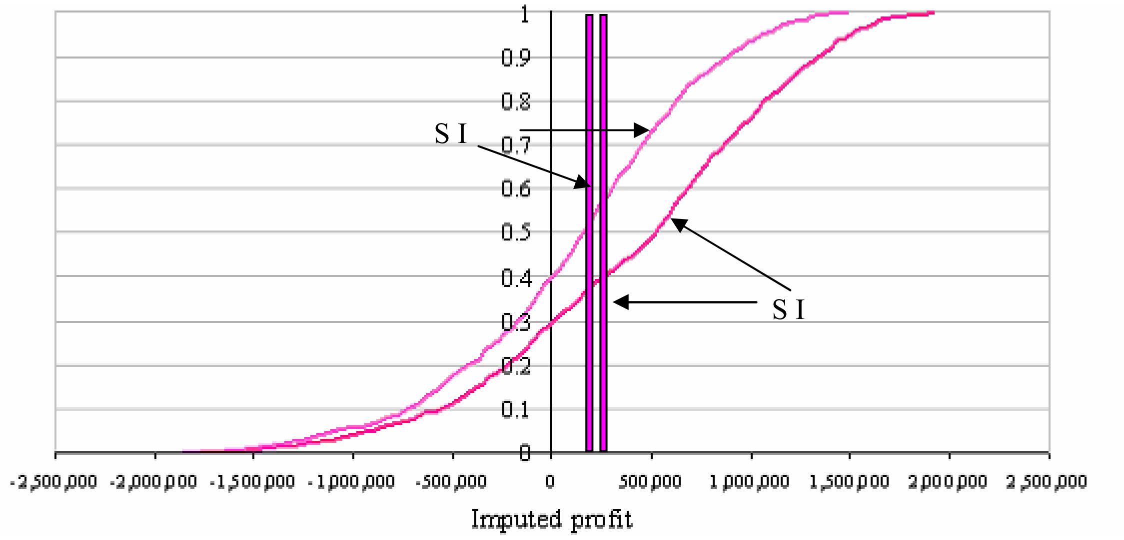


Source: Own representation base on the data from Rauh, 2008

When the project operates under the situation of Scenario II (see Figure 49), the project may have a greater chance of accruing profit of about 50 thousand RMB, and a loss of about -820 thousand RMB to -150 thousand RMB. Thus, the maximum loss amountes to -2.1 million RMB and the maximum profit is estimated to be 1.2 million RMB (see Annex 3).

For the distribution function, Scenario I and II are illustrated in Figure 50.

Figure 50: Distribution function of biogas project with Scenario I and II



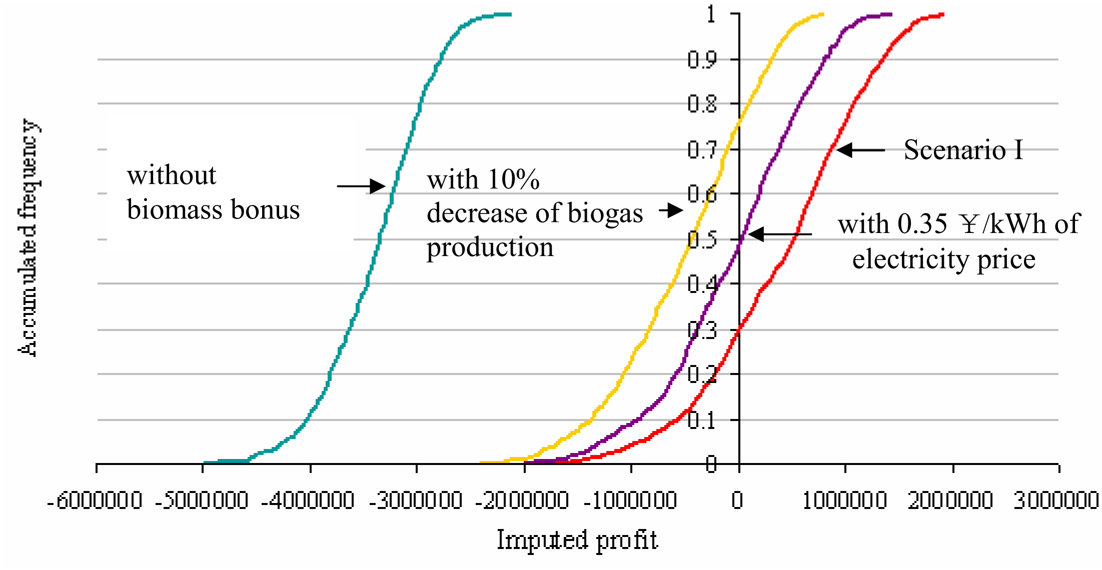
Source: Own representation based on the data from Rauh, 2008

The curve indicted in red shows that the project can be operated profitably with a 70% possibility of success. Moreover, the project accounts for a maximum loss of –1.75 million

RMB and a maximum profit of 2 million RMB. The pink curve indicates the project operating with Scenario II with the maximum loss of -1.7 million RMB and maximum profit of 1.4 million RMB. In that context, the project has a 60% possibility of accruing profit. There are 55 % and 35 % possibilities for the first and the second scenarios to yield profits respectively (see Annex 3).

The distribution function can also be made for profit/ loss concerning each of the following changing factors, for example, the project operated without biomass bonus, with 10% reduction in the price of electricity, and also a 10% reduction in biogas production, etc. Thus, the effect of change in essencial parameters in imputed profit can be made for both scenarios. This calculation is presented in Annex 3, The results can be illustrated in Figure 51 and 52.

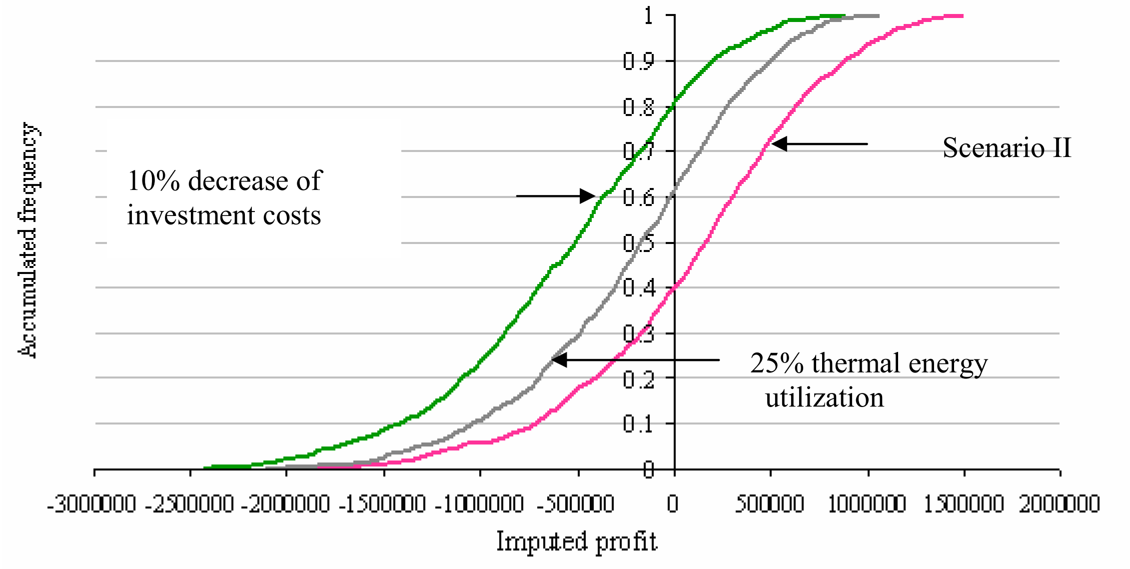
Figure 51: Distribution function from effect of some essential factors changing for Scenario I



Source: Own representation based on the data from Rauh, 2008

In Figure 51 if the project would operate without biomass bonus, the project would have an absolute loss. If the project had been operated with a 10% decrease in biogas production, the project would have had a 25% possibility of earning a profit. If the electricity price were assumed to be 0.35 RMB/kWh, the project would have had 50% chance of accruing profit (see Annex 3). It was also the same situation for Scenario II (see Figure 52). In Scenario II, a 10% decrease in investment costs and only 25% of thermal energy utilization had been calculated for the project (see Annex 3). In Figure 52 is illustrated the effect of essential parameters in imputed profit for Scenario II.

Figure 52: Distribution function from effect of some essential factors changing for Scenario II



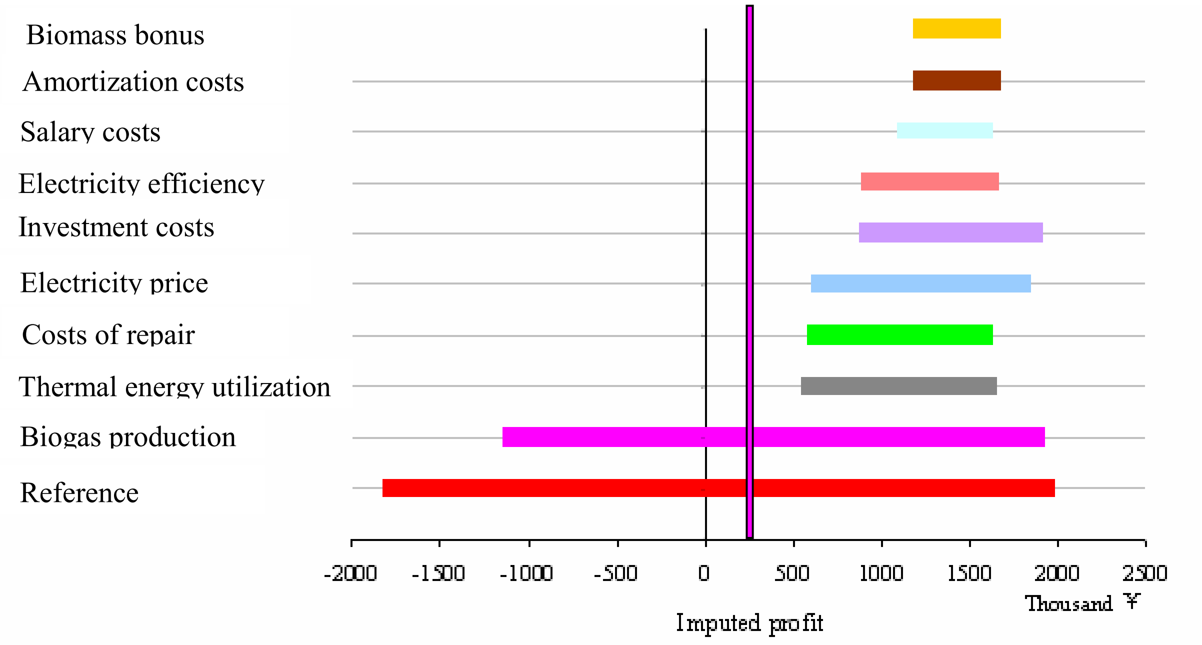
Source: Own rerpretation base on the data from Rauh, 2008

The project had operated with the 10% decrease in investment costs, the project would have had 20% possibility of accruing profit,. Considering the project with 25% of thermal energy utilization, the possibility of accruing profit would have been estimated to be 40% (see Annex 3).

Thus, the most sensitive factor for both scenarios can be considered as the biomass bonus, and other factors in costs evaluation will also be more or less influential on the success of the project.

Every single factor has influence on imputed profit. The imputed profit can be made with the variation of each of factors, this showing which factors had more influence on imputed profit. The calculation for imputed profit band is indicated in Annex 3 for both Scenario I and II. Figure 53 and 54 present the imputed profit band for both scenarios.

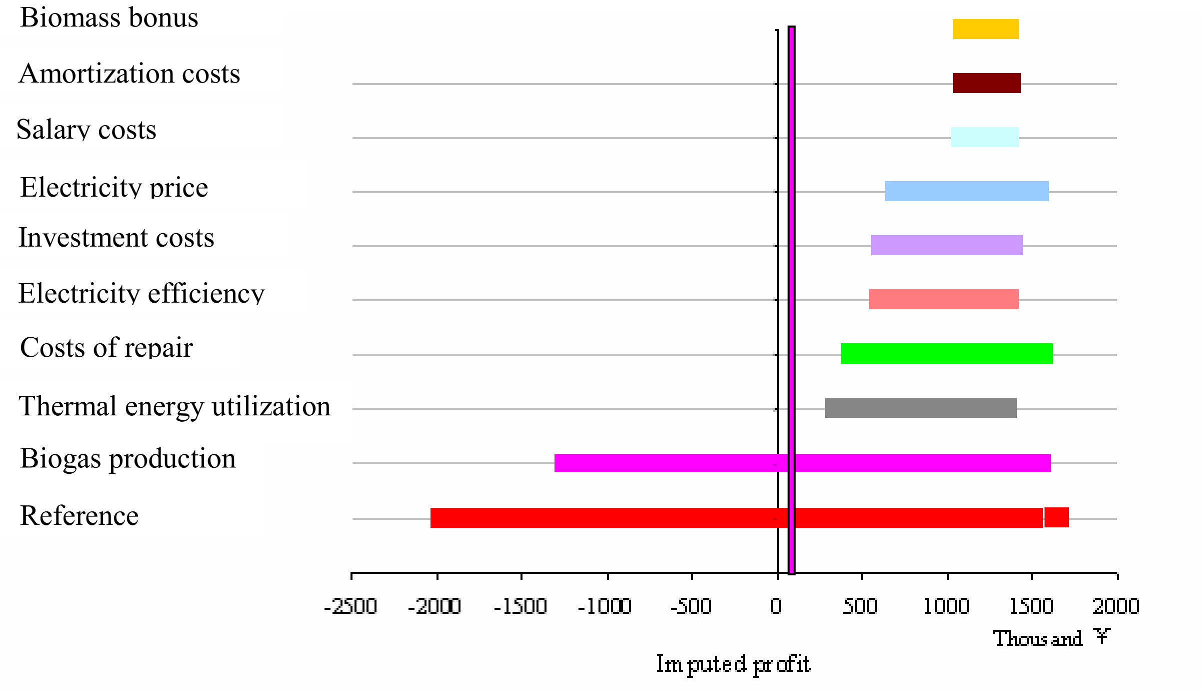
Figure 53: Imputed profit band for biogas digester with Jenbache CHPP



Source: Own interpretation base on the data from Rauh, 2008

The imputed profit band for Scenario II showed in Figure 54.

Figure 54: Imputed profit band for biogas digester with Shengdong CHPP



Source: Own interpretation base on the data from Rauh, 2008

In Figures 53 and 54, when only the biogas production factor changed, the imputed profit was also influenced more by this factor alone than any others. The factors of thermal energy utilization, costs of repair, price of electricity, as well as investment costs accounted for the same imputed profit. Nevertheless, other factors also have an effect on imputed profit. For the two scenarios, the imputed profit possibility depended completely on the single factor of biogas production. In addition, the pink vertical line indicated the most probable profit accrued, and it depended on biogas production (see Annex 3).

The economic analyses are completed for this selected large scale biogas electricity project. Although this project has obtained financial support from the Beijing government and a biomass bonus, the profit showed in cost-revenue analysis is limited. Moreover, the cash flow and liquidity shows negative result. However, one of the important aims for the biogas projects is ecological benefits. Apart from that, the ecological analysis may also provide income for the project owner. Thus, the Chapter 4.3.2 will present ecological analyses.

4.3.3 Ecological analyses

This part will present the ecological analyses including the carobon dioxde emissions analysis, the costs of GHG emission reduction, as well as the financial situation relting to the CDM project.

In reality, this project is in the process of applying to become a CDM project. Concerning the methodology described in Chapter 3.2, there are three barriers which should be discussed. In the case of barriers analysis, the situation of this large scale biogas project is similar to the situation of the medium scale project (see Chapter 4.2.3). Moreover, due to the large scale of the project, although the project receives initial financial support from the Beijing governmen, this sum of money is, however, only for project construction. The project owner must continue to pay operation costs. In this case, the project owner would not take the initiative to use the advanced technology. The economic analyses show that the project has already a limited profit based on both scenarios. Moreover, the cash flow for both scenarios is under zero. Apart from that, manure treatment falls under the category of a public service (for the public good), beyond the production scope previously defined for anmal farms. In view of that, the investment barriers are very obvious. The livestock producers do not have the capacity for investment in this project activity without the CDM.

With respect to technical barriers, the project used an advanced LIPP technology use for anaerobic digester and also a CHPP technology from Austria. At present, the operation and maintenance expertise is extremely limited for large scale biogas project in China. Moverover, most animal farms are short of skilled and properly trained manpower to operate and maintain the technology. In this context, the income of the CDM may help to support the operation and maintenance of such biogas projects.

Concerning the other barriers, there are problems due to prevailing practice, This is the largest chicken farm with biogas electricity project. There has been no similar projet to date in operation in Beijing.

Thus, for the CDM project, the carbon dioxide emissions and costs of emission reduction will be presented, as well as the financial situation connected with CERs.

4.3.3.1 Carbon dioxide emissions analysis

As has been seen, both scenarios are viewed as unprofitable with financial liquidity extending over a time-period of 20 years. But the biogas project would be a substitute for the use of fossil fuels and that is how it can result in a reduction of carbon dioxide emissions. Within the framework of CDM according to the Kyoto Protocol, the carbon dioxide emission reduction could be sold to industrialised countries. In this context, the carbon dioxide emission reduction would be calculated by using the CDM methodology for manure management system (see Chapter 3.2.1).

Baseline emissions Thus, the calculation can be considered as Annex III-9. Here, the results of the baseline scenario and project activity will be presented, as well as emission reductions (see Annex III-9). Table 46 shows the result of baseline emissions.

Table 46: Baseline emissions

Parameter	$BE_{CH_4,y}$	$BE_{N_2O,ID,y}$	$BE_{elec./heat.y}$	BE_y
Value, tCO_{2e}/a	95,969	3,629	16,762	116,360

Thus, the baseline emissions are the sum of baseline emission of methane production, nitrous oxide production and carbon dioxide emission from electricity and heat utilization, which is estimated to be 116,360 tons per year.

Project emissions As the same situation as for medium scale biogas project (see Chapter 4.2.3), the PE_y is estimated to be the sum of $PE_{AD,y}$, $PE_{Aer,y}$ and $PE_{N_2O,y}$. Thus, the project emission for this project shows in Table 47.

Table 47: Project emission

Parameter	$PE_{AD,y}$	$PE_{Aer,y}$	$PE_{N_2O,y}$	$PE_{elec./heat.y}$	PE_y
Value, tCO_{2e}/a	9,789	13	3,812	1,014	1,4055

Thus, the emissions from project activity are estimated to be 13,014 tons annually, which are the sum of leakage of methane emissions and methane emissions from aerobic treatment, as well as that of nitrous oxide (see Annex III-10).

Leakage emissions The leakage from baseline and project emission would be considered as zero, as there is no fertilizer to apply to the land directly after biogas treatment, as all of the biogas residue must be prepared for organic fertilizer production.

Emission reduction As a result, the total emission reduction can be indicatd in Table 48.

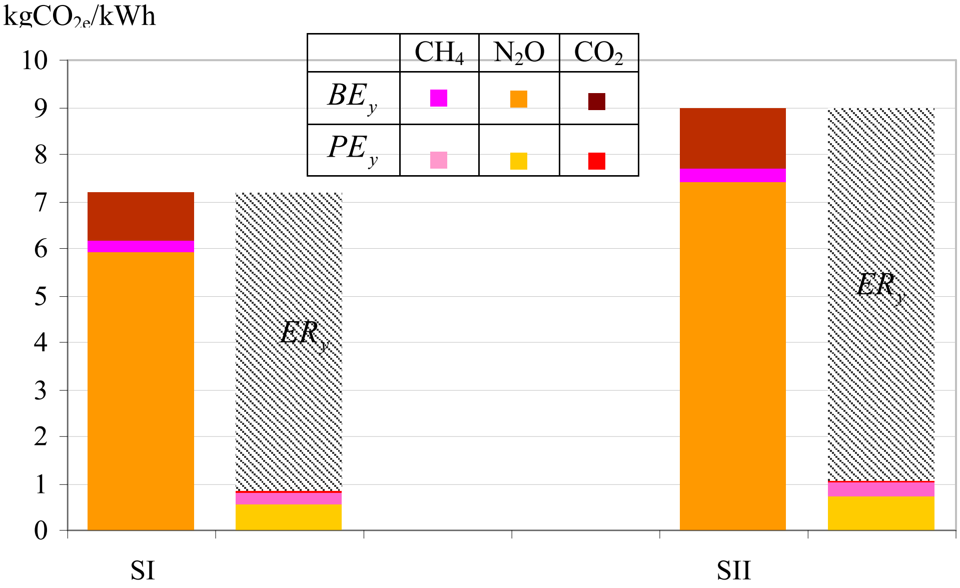
Table 48: Emission reduction

Parameter	BE_y	PE_y	ER_y
Value, tCO_{2e}/a	116,360	14,055	102,305

Thus, the emission reduction can be estimated as 102,305 tons carbon dioxide annually. Next section will present the costs of carbondioxde emission reduction.

Thus, the BE_y, PE_y and ER_y can also be estimated for electricity production. This is shown in Figure 55.

Figure 55: Baseline emissions, project emissions, leakage emissions and emission reduction for electricity generation related to Scenario I and II



In Figure 55, it can be seen that although the amount of GHG emission and emissin reduction are the same for both scenarios, but they are different for electricity generation. In this context, comparing two scenarios, Scenario I has less GHG emission production, as well as also less emission reduction. The reason is Scenario I has less electricity production than Scenario II, based on the same amount of chicken waste production. Thus, in the next part the costs of GHG emission reduction will be presented.

4.3.3.2 Costs of carbon dioxide emission reduction

The carbon dioxide emission reduction costs will be calculated for both scenarios. Firstly, the carbon dioxide production costs for the biogas project must be estimated from the difference between the carbon dioxide costs generated from electricity production and thermal energy revenue resulting from electricity production. Then the carbon dioxide costs for coal consumption must also therefore estimated.

Next, the carbon emissions per kilowatt hour electricity production must be evaluated as the difference between carbon emissions in the biogas project produced by electricity production and those emissions produced by thermal energy production. Then the carbon emission from coal consumption would be also calculated.

The relationship between the carbon costs difference between biogas production and coal consumption with carbon emission reduction will be estimated for carbon dioxide emission reduction costs. Table 49, 50 and 51 present the above mentioned calculation for Scenario I.

Table 49: Difference in costs of electricity between biogas production and coal consumption for Scenario I

Calculated costs of electricity production in the biogas project, RMB/kWh$_{el}$		Costs of coal consumption, RMB/kWh$_{el}$
From electricity genearion	From thermal energy revenue	From electricity generation
0.59	0.051	0.53
Difference 0.543		
Difference 0.013 RMB/kWh$_{el}$		

Table 49 illustrates the difference of costs in biogas project and coal consumption, which are calculated to be 0.013 RMB/kWh$_{el}$. The carbon dioxide emission reduction is showed in Table 50.

Table 50: CO_2 emission reduction between biogas production and coal consumption for Scenario I

CO_2 emissions in biogas project, t/kWh$_{el}$		CO_2 emissions from coal consumption, t/kWh$_{el}$
From electricity production	Thermal energy production from coal consumption	From electricity production
0.00087	0.00013[16]	0.00096[17]
Difference 0.00074		
Difference -0.00022 t/kWh$_{el}$		

---

[16] CO_2 emissions of thermal energy production from coal consumption are equal to CO_2 emissions from coal for heat production of 2044 t/a divided by electricity production of 16,170,000 kWh/a. Here, CO_2 emissions from coal for heat production is equal to coal consumption of 768.45 tons multiplied by emission factor of coal of 0.0026 tons. Moreover, the coal consumption of 768.45 tons is equal to thermal energy production of 6,247,500 kWh/a multiplied by thermal value of coal of 0.00813 kWh/t.

[17] CO_2 emissions of electricity production from coal consumption are equal to CO_2 emissions from coal for electricity production of 15,472 t/a divided by electricity production of 16,170,000 kWh/a. Here, CO_2 emissions from coal for elelctricity production is equal to coal consumption of 5817 tons multiplied by emission factor of coal of 0.0026 tons. Moreover, the coal consumption of 5817 tons is equal to electricity production of 16,170,000 kWh/a multiplied by electricity value of coal of 0.00278 kWh/t.

In Table 50, the difference of carbon dioxide emissions in the biogas project and coal consumption are calculated, resulting in -0.000278 t/kWh$_{el}$ The emission duction costs are indicated in Table 51.

Table 51: CO_2 emission reduction costs for Scenario I

<table>
<tr><th>Difference in costs of CO_2 between biogas production and coal consumption, RMB/kWh$_{el}$</th><th>CO_2 emission reduction between biogas production and coal consumption, t/kWh$_{el}$</th></tr>
<tr><td>0.013</td><td>-0.00022</td></tr>
<tr><td colspan="2">Relation
-61.76
RMB</td></tr>
</table>

Thus, as a result, the costs of carbon dioxide emission reduction is estimated to be 61.76 RMB/t with the division of carbon dioxide costs difference and carbon dioxide emission reduction. After completing the carbon dioxide emission reduction costs calculation for Scenario I, a similar procedure is used for calculating for carbon dioxide emission reduction costs of Scenario II, which are indicated in Table 52, 53 and 54.

Table 52: Difference in costs of electricity between biogas production and coal consumption for Scenario II

<table>
<tr><th colspan="2">Calculation costs of electricity production in the biogas project, RMB/kWh$_{el}$</th><th>Costs of coal consumption, RMB/kWh$_{el}$</th></tr>
<tr><td>From electricity generation</td><td>From thermal energy revenue</td><td>From electricity generation</td></tr>
<tr><td>0.61</td><td>0.059</td><td>0.53</td></tr>
<tr><td colspan="2">Difference
0.55</td><td></td></tr>
<tr><td colspan="3">Difference
0.02
RMB/kWh$_{el}$</td></tr>
</table>

As seen in Table 52, the different in costs between the biogas production and coal consumption calculation is computed to be 0.02 RMB/kWh$_{el}$. The carbon dioxide emission reduction between biogas production and coal consumption for Scenario II is shown in Table 53.

Table 53: CO_2 emission reduction between biogas production and coal consumption for Scenario II

CO_2 emission in biogas project, t/kWh_{el}		CO_2 emission from coal consumption, t/kWh_{el}
From electricity production	Thermal energy production from coal consumption	From electricity production
0.0011	0.00016[18]	0.00096[19]
Dufference 0.00094		
	Difference -0.00002 t/kWh_{el}	

In Table 53, the difference in carbon dioxide emissions from biogas production and that from coal consumption is estimated as being $0.000096 t/kWh_{el}$. Thus, the costs of emission reduction are shown in Table 54.

Table 54: CO_2 emission reduction costs for Scenario II

Costs difference between biogas production and coal consumption,RMB/kWh_{el}		CO_2 emission reduction between biogas production and coal consumption, t/kWh_{el}
0.02		-0.00002
	Relation -1273.66 RMB	

The costs of carbon dioxide emission reduction are computed as being 208 RMB/t CO_{2e} (see Table 54).

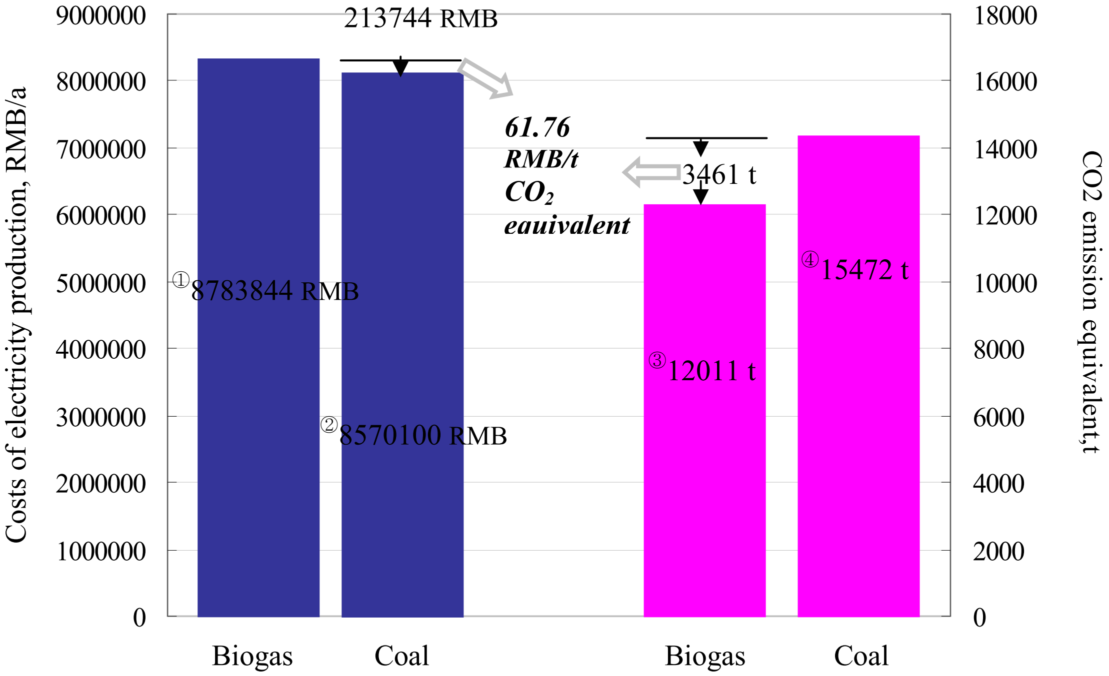
The carbon dioxide costs of electricity production and carbon emission production equivalent are illustrated in Figure 56 and 57 for both scenarios.

---

[18] CO_2 emissions of thermal energy production from coal consumption are equal to CO_2 emissions from coal for heat production of 1880 t/a divided by electricity production of 12,936,000 kWh/a. Here, CO_2 emissions from coal for heat production is equal to coal consumption of 706.98 tons multiplied by emission factor of coal of 0.0026 tons. Moreover, the coal consumption of 706.98 tons is equal to thermal energy production of 5,747,700 kWh/a multiplied by thermal value of coal of 0.00813 kWh/t.

[19] CO_2 emissions of electricity production from coal consumption are equal to CO_2 emissions from coal for electricity production of 12,377 t/a divided by electricity production of 12,936,000 kWh/a. Here, CO_2 emissions from coal for elelctricity production is equal to coal consumption of 4653 tons multiplied by emission factor of coal of 0.0026 tons. Moreover, the coal consumption of 4653 tons is equal to electricity production of 12,937,000 kWh/a multiplied by electricity value of coal of 0.00278 kWh/t.

Figure 56: Costs of CO_{2e} of electricity production and CO_{2e} for Scenario I



Notes:

①*CO_2 costs of electricity production are equas to 0.54 RMB/kWh$_{el}$ of CO_2 costs for biogas project multiplied by 1617000 kWh of electricity production.*

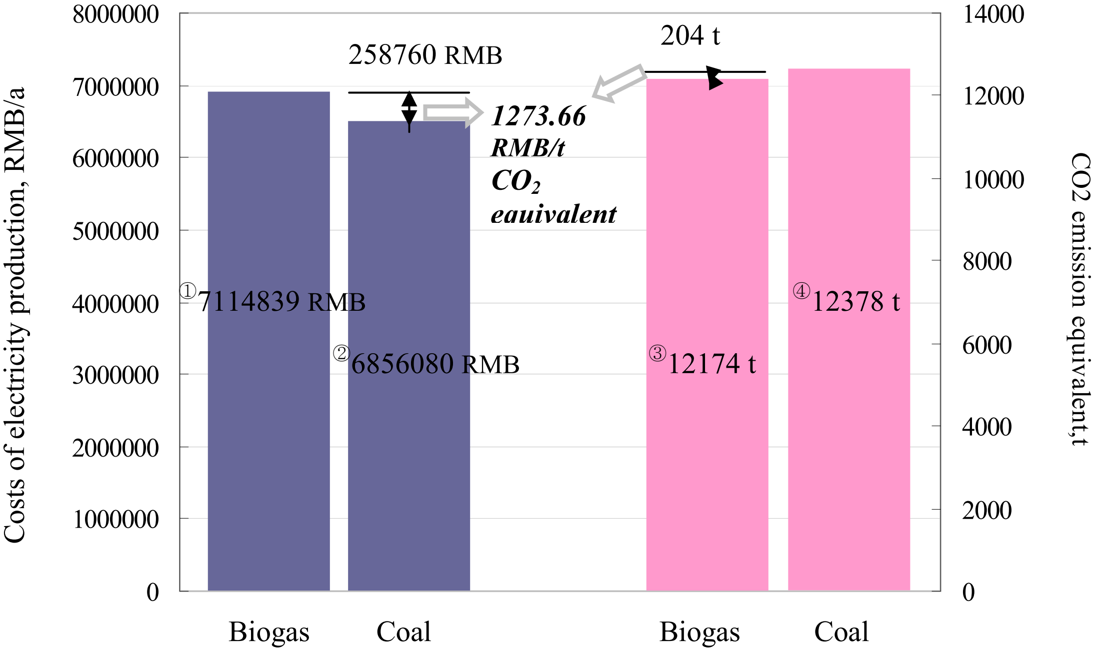
②*CO_2 costs of electricity production are equal to 0.53 RMB/kWh$_{el}$ of CO_2 costs for coal consumption multiplied by 1617000 kWh of electricity production.*

③*CO_2 emission equivalent are equal to the difference between 14055 tons of CO_2 emission from biogas production and 2044 tons of CO_2 emission from coal consumption for heat production.*

④*CO_2 emission equivalent are equal to 15472 t of CO_2 emission from coal consumption for electricity production.*

The situation for Scenario II is shown in Figure 57

Figure 57: Costs of CO_{2e} of electricity production and CO_{2e} for Scenrio II



Notes:

①costs of CO_{2e} of electricity production equals to 0.55 RMB/kWh$_{el}$ of costs of CO_{2e} for biogas project multiplied by 1,293,600 kWh of electricity production

②costs of CO_{2e} of electricity production equals to 0.53 RMB/kWh$_{el}$ of costs of CO_{2e} for coal consumption multiplied by 1,293,600 kWh of electricity production

③CO_{2e} emissions equals to the difference between 14,055 tons of CO_{2e} emissions from biogas production and 1,881 tons of CO_2 emissions from coal consumption for heat production

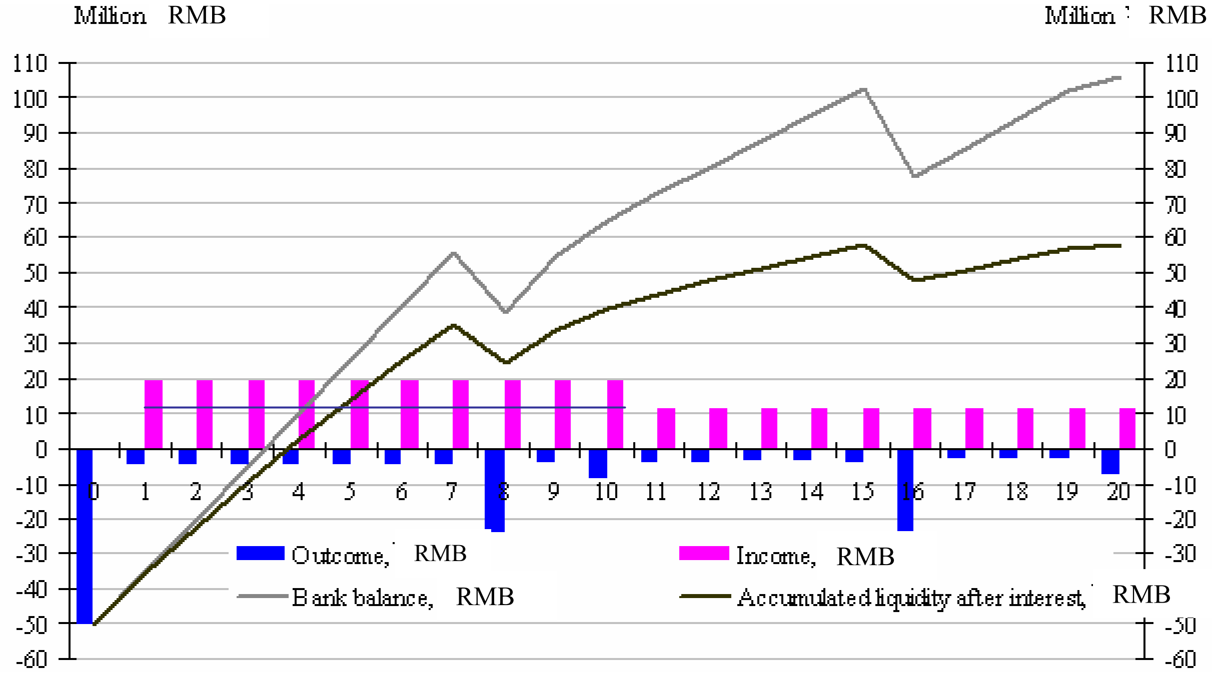
④CO_{2e} emissions equals to 12,378 tons of CO_{2e} emissions from coal consumption for electricity production

Thus, the financial situation can be calculated after conrbon dioxide emission reduction calculation has been completed. After this the CDM revenue can be added into project income.

4.3.3.3 Cash flow and liquidity (with CERs)

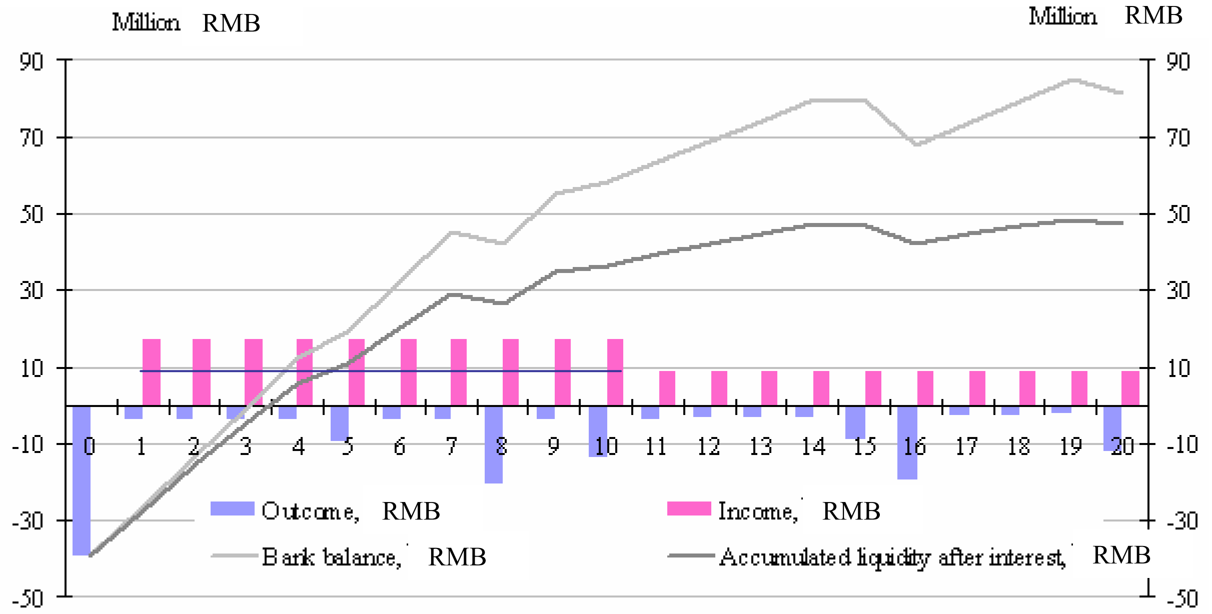
In realisation, the carbon dioxide market price (price of CERs) would be taken as 10 \$/t CO_{2e}, and in order to apply for a CDM project, the CDM project preparation costs must be paid. Currently, as experience shows the total costs of applying for the CDM would not exceed 200 thousand \$ for such a large scale of project. In case of reapplication of the project idea, the costs would, however, not exceed 250 thousand \$. This project with Scenario I and II has been unproductive as far as the financial liquidity situation (see Figure 49 and 50) is concerned, so it will be interesting to find out whether the project would be considered profitable or not, in terms of consideration as a CDM project. The calculation for cash flow and liquidity is presented in Annex 3 for both scenarios. The financial situation for both scenarios is indicated in Figure 58 and 59.

Figure 58: Financial liquidity with carbon price of 10 $/tCO_{2e}$ equivalent and proposed maximum CDM preparation costs for Scenario I



The cash flow and liquidity will be presented in Figure 59 for Scenario II.

Figure 59: Financial liquidity with carbon price of 10 $/tCO_{2e}$ equivalent and proposed maximum CDM preparation costs for Scenario II



In Figure 58 and 59, both scenarios have been calculated based on absolute profit. The difference between Figure 58 and 59 can be explained thus. Firstly, the total costs include 200 000 $ for both scenarios, from which the proposed 50% must be paid by this farm. It means that 100 000$ can be considered as bank loan from 7.83%. Secondly, the annual income for the first 10 years is calculated in addition to the revenue generated from the sale of CDM, which is 10$/t$CO_{2e}$ with the emission project production of 111,325 t/CO_{2e} for both of scenarios. The third point is that the annual outcome is computed by adding the annual base rate and repayments for the 20 years back loan, so that when both scenarios are estimated with the CDM revenue and costs. Thus, the investments costs, annual income and outcome must be higher, but at the end of 20th year, the accumulated liquidity is estimated to be 57.85 million RMB for Scenario I and 47.32 million RMB for Scenario II. The balance of profit and loss would be noted, when the carbon price had been computed as 5.19 RMB/ tCO_{2e} (0.70 $/ t$CO_{2e}$) for Scenario I and 17.90 RMB/ tCO_{2e} (2.39 $/ t$CO_{2e}$) for Scenario II. In view of that, both scenarios with CDM implementation would operate much better than without (see Annex 3).

After the initial analysis, the results will be discussed. This will be followed by the discussion and conclusion.

5 Discussion and conclusion

This chapter presents a discussion based on the economic and ecological analyses for the three selected projects in China. The three projects are, however, also compared with German biogas projects.

5.1 Economic and ecological aspects for selected three biogas projects

This section discusses the economic and ecological aspects of three selected biogas projects. The specific points for discussion include; project background, government bonus as well as the impact on CDM.

5.1.1 Project background

The data from all three projects are documented by MOA China. These three projects are very typical of all biogas projects in China. Moreover, they operated relatively sucssesfully, compared with other biogas projects in China. However, in China there are many biogas projects which have not been as well implemented as these three selected projects. One reason could be the different background considering the project's site and situation.

Project 1: A household biogas project The first project is a household biogas project, which is located in Hubei provice. The project aim is to replace fossil fuels with the use of biogas thereby dealing with the problem of 33,000 households which depend on thermal energy. This project is well implemented, not only because the technology of individual household biogas project has already been well developed, but also it has a very good background. For instance, the participating farmers obtained financial help of The World Bank and Chinese government countypart funding (see Chapter 4.1). In this context, farmers are relieved of the problem of lack of finance. Moreover, with the assistance from Chinese National Commitment and Reform this project sucsseefully applied for a CDM project. In reality, the carbon dioxide emission reduction was sold to The World Bank for 10 $ per ton.

Thanks to the REL established in the year 2006, the individual househould biogas projects obtained governmental support. The sum for support depends on the local governmental financial capability. In recent years this governmental support could be 50% of total investment costs in more highly developed location. Normally these locations are in the eastern part of China. However, there is also a large population living below average of rural living standards in the west-middle part of China. This group of people cannot easily cosume fossil energy and also need clean energy for their livelihood. In this case, households in the west-middle part of China, needs to spend twice the cost for the same amount of biogas production and thermal energy utilization as is the case in a more advanced region, especially if the region fails to secure financial support.

Project 2: A medium scale biogas electricity project The different project background may have more influence in the medium scale biogas electricity project, too. The medium scale biogas electricity project described in Chapter 4.2 represents the second project for economic and ecological analysis in this study. This is a 2000 head dairy-farm project located in Zhejiang province. The project aim is to solve the problem of waste pollution created by keeping diary-cows. At the same time, the project also aims to replace fossil fuel needs with the use of electricity and thermal energy, in other words, with pure national technology for use by the local farm and company as well as selling the generated electricity and feeding it into the national grid for local income generation. The project owner has to seek financial support by himself or herself when intending to sell the electricity generated. Furthermore, although this project had not been prepared for application for a CDM project to gain profits, the large amount of greenhouse was also reduced.

Considering Scenario II for example, the medium scale biogas project in 4.2 indicated that 50% of the investment costs were connected to a bank loan. In the context of getting government support, the nature of profit would be much better than Scenario II. Thus, Scenario II is considered as case I, in which, the project owner needs to seek finance by himself or herself. The case where the project obtains 50% financial support from the government can be considered as case II. The difference in costs between the two cases with different source of investment is presented in Table 55.

Table 55: Costs difference between two cases with different investment sources

Components, RMB/a	Value	
	Case I	Case II
Interest charges① 6.8% of investment costs for case I. 5.76% of investment costs for case II	**195,859**	**165,904**
Amortization 3 years of lifetime for CHPP. 5, 8 and 10 years life time for equipments	204,469	
Costs of repair 5.5% of investment costs	255,922	
Costs of insurance 0.5% of investment costs	23,267	
Costs of payment of salaries	30,000	
Process energy costs②	53,808	
Other costs	93,062	
Total annual imputed costs	856,386	826,430

Source: see Table 31

Notes:
The sum of investment is 4,653,120 RMB for both case I and II
① *The bank loan can be considered as 6.8% for case I , 5.76% for long-term deposit and bank loan 7.65%. The interest charges are calculated with the capital commitment of 61.9%*
② *The process energy factor is regarded as 7% from electricity energy production*

Table 55 shows the nature of costs for case I and II. The same amount of investment costs for both case I and II can be identified. In this context, only the interest charges are different between two cases. Case II has fewer interest charges than case I. The reason is that case II is financed by Chinese government. As a result, the total annual imputed costs in case II is computed to be less than 30 thousand RMB annually compared with that of case I.

Thus, with the same amount of electricity generation and thermal energy utilization for both cases, the profit is different due to the different annual imputed costs. The imputed costs, revenue and profit are stated in Table 56.

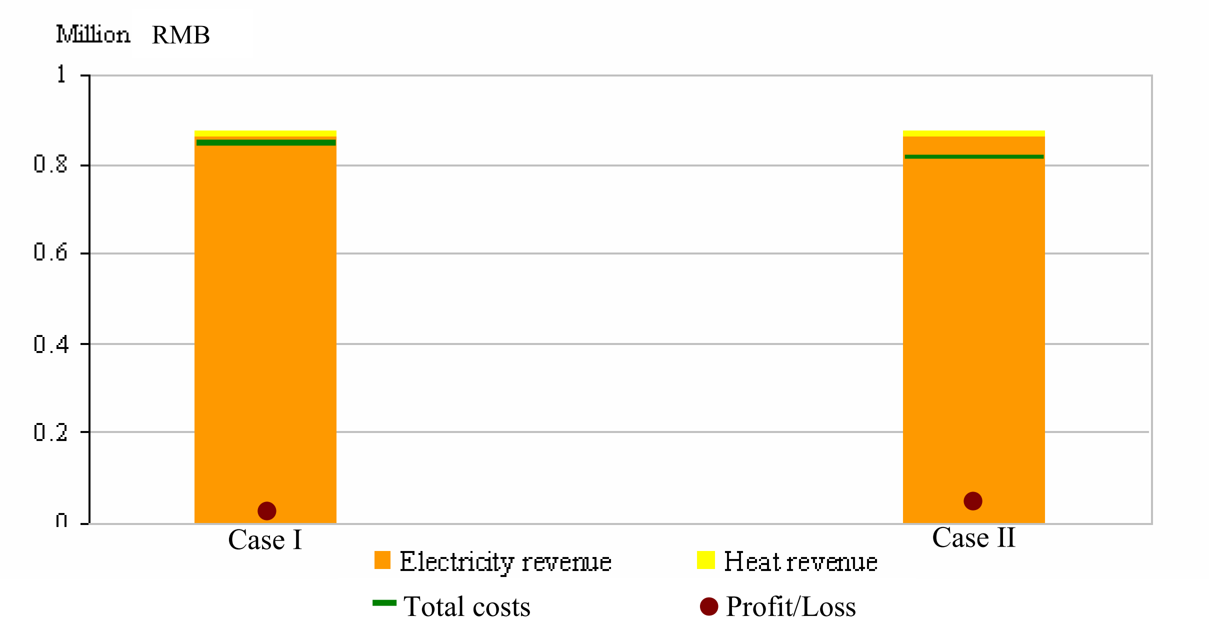
Table 56: Costs, revenue and profit related to the second project

Components, RMB/a	Case I①	Case II②
Total annual imputed costs	856,386	826,430
Annual revenue	870,477	870,477
Profit/loss	14,091	44,046

Note:
① *Compared with Chapter 4.2*
② *Compared with Table 55*

The costs, revenue and profit/loss situation can also be indicated in Figure 60

Figure 60: Costs, revenue and profit for case I and II relating to the second project



Considering Figure 60, with the same amount of generated electricity and thermal energy utilization, the generated profit is greater in case II than in case I. This is because 50% of the total investment costs are financed by governmental support. In the context of case II, the project owner would ensure that the project runs better. Furthermore, if the project operates with case II, the project stand a greater chance of acuring profit.

Moreover, the result in Chapter 4.2 indicates that Scenario II operates much better than Scenario I. In view of this, Scenario II is proposed for the generation of biogas electricity for feeding into national grid. In this context, all the waste on the dairy-farm is used for biogas production. Scenario I is the biogas project for electricity and thermal energy utilization using 20% of the waste locally. However, it cannot be inferred that Scenario II is better than Scenario I in any event. It could be that for China's biogas projects, many factors are not stable, for instance, the price of electricity. In the case of Scenario I, the price of electricity is considered to be 0.52 RMB/kWh$_{el}$. This price fluctuates greatly. Normally the price change could fluctuate between 0.45 RMB/kWh$_{el}$. and 0.70 RMB/kWh$_{el}$. This price fluctuation can also affect Scenario II. The price of electricity which is 0.32 RMB/kWh$_{el}$ can also change because of the difference in project background. In the case of Scenario I, if the price of electricity were 0.70 RMB/kWh$_{el}$, and the rest, 80% dairy waste were earmarked for fertilizer production (as is the actual case in Scenario I, see Chapter 4.2.1), the profit could be much better than in Scenario II.

Project 3: The Beijing Deqingyuan biogas electricity project (the third project in this study) has benefited from generaous financial support from the Chinese government. This project is one of the largest biogas electricity projects in China. With the huge amount of daily waste production of 212 tons and waste water of 318 tons, the Deqingyuan farm has the capacity necessary to entitle it to become the largest biogas electricity project. This project is a key national biogas project. 50% of the investment costs for this project are financed by governmental support. This project operates with a full range of technology both from local and international businesses involved in biogas electricity generation. Undoubtedly, the electricity generated can be sold and be fed into the national grid. However, not all large scale biogas electricity projects can receive governmental support and a good price for electricity production as is the case for this very project. One of the first biogas electricity generation projects with Shandong Minhe farm is a good example of such projects. This project received 30% funding from The World Bank and 70% from own sources. The project needs to pay interest charges. The price of electricity was less than that of the Deqingyuan project.

Thus, the project background plays a very important role for biogas projects in China. Due to the differences in location, living standard and government support, etc., the impact of the project may be felt differently. However, on the part of government, there is the need for setting standards more or less with the same conditions for all the biogas projects. Otherwise, before the project operates, the project owner may not be in the position to easyly receive the right result as analysed. Moreover, for the government, the biogas projects are not easily supervised.

Biogas projects bring obvious ecological benefits. With the ecological benefits, project owners try to obtain more possible economic benefits. In order to obtain more profit, more and more biogas generation projects operating based on the “cycling ecological-economics” model have been established in China. This model has withnessed an exponential growth in China.

This is especially the case for large scale biogas electricity projects. In view of this, some medium and large scales biogas projects use produced fertilizer for arable farming.

Furthermore, the data change should also be considered in this study. Some biogas projects in China could benefit from additional government support after operating for some time. This takes into account the future expansion of farms sizes. A good example is Shandong Minhe biogas electricity generation project, which was the first biogas electricity generation project to be implemented within the context of CDM. In 2006, Shandong Minhe project with 50 million RMB of investment costs and 10 \$/t CO_{2e} successfully applied for a CDM project. After two years, the project was again successful with the total investment costs of 63.88 million RMB and 15 \$/t CO_{2e} (see unfccc, 2009). The reason for this achievement is that the farm size increased and finance was availble.

The data for the Deqingyuan biogas electricity generation project was received in March 2008. At that time, the Deqingyuan project was not yet in operation. Taking a closer look at the homepage of Deqingyuan, one sees a change in investment costs to 65 million RMB including fertilizer preparation. This took effect from April 2009. Thus, the dissertation presents three project analyses based on the data from the general publication of UNFCCC and MOA China as of the year ending 2008. Therefore, any different result for these projects from other authors could be also valid.

The background to the project has already been discussed. The issue concerning government bonus is one of the key points for discussion.

5.1.2 Government bonus

The second point is discussed considering the government bonus with reference to electricity generated for feeding into the national grid.

Considering the REL for the year 2006, the generated electricity for feeding into national grid could be as much as 0.25 RMB/kWh_{el}. It is in the light of this that more project owners want to work on biogas electricity projects. However, not all the projects can be profitable (for example, the medium scale project described in Chapter 4.2). Compared with German REAS, between the year 2000 and 2009 the latter underwent amendment twice after it was promulgated. Concerning this, the type of bonuses are classified according to different type of projects (see Chapter 2.2).

In recent years, the government support biogas projects increased. The initial investment costs of 2 million RMB from government support should not exceed half of the total investment costs. This would more or less like a gift from the government. In reality, due to the plan of the budget, not all the project onwers receive this bonus. The reason for this vary, it might be dependent on the evaluated quality of the project result and the project applying time, etc. Due to the large amount of money mentioned above, not all project owners can obtain this benefit (see Cahpter 5.1). The initial investment costs from government support could be very well implemented for household biogas projects, due to the size normally ranging between 8 m^3 and 20 m^3. In view of that, the technology for household biogas projects is already matured. Once the household biogas project had commenced operations, it could be successful with a very good research plan.

However, compared with household biogas projects, the biogas electricty generation projects needs high quality of state-of-the-art technology excellent research plan. Moreover, the project risk depends on project operation, project background and many unforesseable factors (for instance, price of electricity and thermal energy, the amortization costs, etc). Once a project has obtained initial investment costs support, if, operated unsuccessfully, that means the relative large initial investment costs are wasted. In this context, if the initial investment costs can be provided for each year (or several years) depending on the project operation, the government would be relieved the financial burden. In this case, more project owners could receive a bonus each year (or for several years). The government could also better check on how the project operates. The project owner may be better motivited to care for the project..

The above mentioned situation can be analysed for medium scale biogas electricity projects as an example. In the case of Scenario I, the project does not need a bank loan. In this context, the project is unprofitable. In the case of Scenario II (see Chapter 4.2), the produced electricity is meant for sale to be fed into the national grid. The investment costs constitute two elements. The initial is 50% of owner capital and the second 50% is that of bank loan. Each year, the same amount in terms of bonus is obtained from 2 million RMB. In this case, the result must be better than in Scenario II (see Chapter 4.2). Thus, the indication of costs, revenue and profit or loss situation as an example for medium scale biogas project are presented in Table 57.

Table 57: Costs, revenue and profit/loss situation for medium scale biogas project

Components, RMB/a	Case I①	Case III②
Total annual imputed costs	856 386	856 386
Annual revenue	870 477	870 477
“Bonus”		100 000
Profit/loss	14 091	114 091

Notes:

① *Compared with Chapter 4.2*

② *In the case of 2 millionRMBseperated from 20 operating years.*

From Table 57, it is easy to understand the context of profit in case III with an annual bonus of 2 millon RMB being the same amount for the 20 years. This is much better than case I (secanrio II). However, the challenge for the project owner is to find the needed financial resources as a prerequisite for project implementation. Moreover, the separeted bonus must be garanteed, otherwise the project is unprofitable (see Chapter 4.2).

In reality, when the bonus is paid on an annual basis from possible innitial government support the projects can be implemented more effectively. In view of that, good research for bonus implementation must be done in future. Concerning China's biogas project situation, the type of bonuses can be described as follows:

- *National technology utilization bonus* For the biogas electricity generation project, which used national technology, can thus obtain a bonus for national technology development. In this case, national technology as a whole will be gain an incentive to be developed.
- *Bonus for animal waste discharge from other locations* For the biogas project farm which also disposes of animal waste from other locations, a bonus can be obtained for animal waste discharge depending on the location distance. In view of that, especially for biogas electricity generation projects, the project will discharge more waste from other locations, close in terms of proximity, and thereby generate more income from biogas and electricity generation.
- *Bonus for west-middle area* The bonus can be obtained for biogas projects located in the mid-west area of China. This is a remote area and needs government support ungently compared to other areas. In this case, the bonus can be obtained, paying low interest and for electricity utilization locally, etc. The bonus for feeding electricity into the national grid can also increased comparing with the usual 0.25 RMB/kWh$_{el}$.
- *Bonus for project with greater priority* The Deqingyuan biogas electricity generation project is one of great importance. This project obtained enormous financial support from the government. For instance, the 50% of initial investment is provided by the Chinese government. However, one key point is that the biogas project is a model for the biogas scene. Not every biogas project with great importance can obtain such generous financial support like the Deqingyuan project. In other words, the government can not finance every key point biogas project with such support like that given to the Deqingyuan project. In this case, the criteria for a key point project must be set-up. In this context, the implementation of the criteria for setting bonuses could also be considered.

The bonus is one of the main points for biogas scene in China. With the rapid development of a number of biogas projects, the bonus must be well researched and successfully implemented. Furthermore, the bonus must help projects to operate more efficiently.. In this case, every detail of project must be well considered and researched in the context of China. It is interesting to note that the same amount of money can generate different effects depending on its utilization.

Beside the issue of government bonuses, the concept of CDM is also very important for discussion. This CDM concept is discussed in the next section.

5.1.3 Impact of CDM

In Chapter 2.2, there are different financing forms for CDM implementation: unilateral, bilaterial and multilateral. Curretly in China, most CDM projects operate with bilaterial and multilateral forms. As indicated in Chapter 4.1, the carbon dioxide emission reduction was sold at the price of 10 \$/t. The price of carbon dioxide emission reduction was 10 \$/t for the Deqingyuan electricity generation project. The price of CO_{2e} for another similar project being unilateral CDM was 15 \$/t. Thus, the Deqingyuan project is a multilateral CDM project. The buyer is The World Bank. This is because the projects are financed by The World Bank (see Chapter 4.1 and 4.3). Moreover, the price of carbon dioxide emission reduction determines the CDM benefit. It also helps in deciding whether the project is profitable for project owner or not. If a biogas project could operate unilaterally, the sitution would be more or less conductive.

In the study, the second project (medium scale biogas electricity generation project), did not apply for a CDM project. In case CDM project is implemented using the utilateral approach, the two results will be different. The explanation is given in Table 58.

The Scenario II for medium scale biogas electricity generation project was financed with 50% of the costs borne by the project owner and the other 50% from a bank loan. The price of carbon dioxide for CDM estimation was 10 \$/t (see chpter 4.2). This is evidenced in case I (see 5.1.1). In view of this, this project can be considered a CDM project which operated using either a bilateral or multilateral approach. As pointed out in Case II, Chapter 5.1.1 the project owner paid 50% of investment costs whiles the remaining 50% is borne by the Chinese government. In this context, the project can be said to a unilateral CDM project.

Thus, the comparison for a CDM project considering cases I and II can be illustrated in Table 58).

Table 58: Impact of CDM on annual imputed costs, revenue and profit/loss concerning the second project

Components, RMB/a	Case I①	Case II②
Total annual imputed costs	856,386	826,430
Total annual revenue	1075,002	1156,812
From biogas project	870,477	870,477
From CDM③	204,525	288,335
Profit/loss	218,616	330,382

Note:

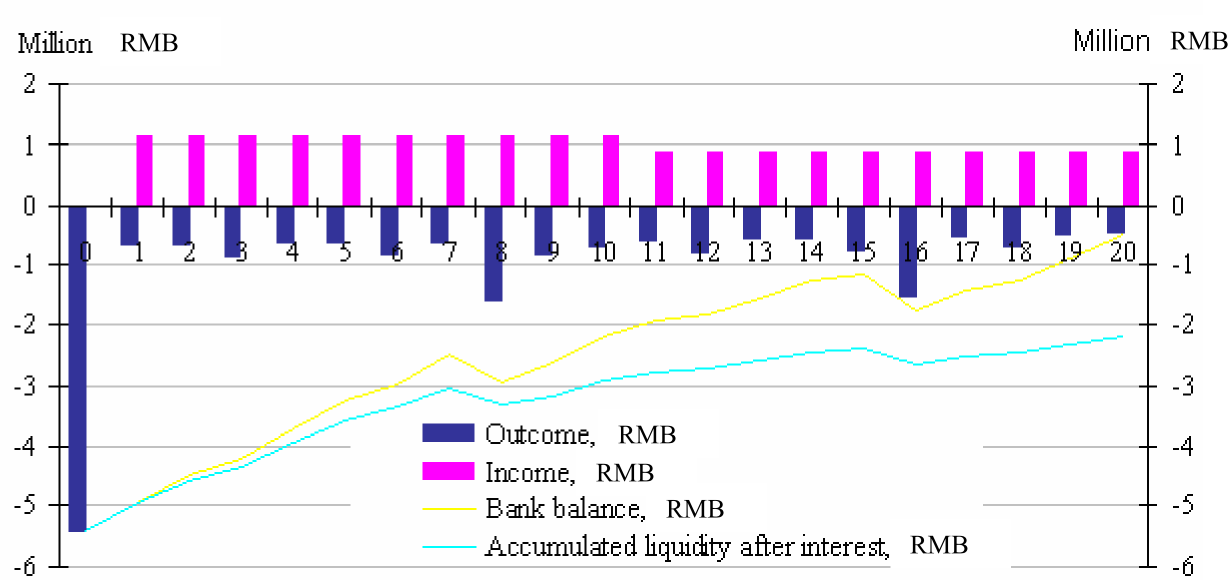
① *Compared with Chapter 4.2*

② *Compared with Table 56*

③ *Case I can be considered as a CDM project with bilateral or multilateral approach, case II-unilateral. The price for carbon dioxide emission reduction was 10 $/ /t for case I, 15 $/t for case II*

In Table 58, the annual imputed costs for case I are more than that of case II. The reason is that case II failed to pay interest charges, that is not so much as in case I (see Chapter 5.1). With the same amount of revnue from the biogas project and the same amount of carbon dioxide emission reduction for both cases I and II, the total revnue for case II is more than that of case I. In view of this, the prices for both cases are different. Case I has a price of 10 $//t$CO_{2e}$ and that of case II is estimated to be 15 $//t$CO_{2e}$ (see Chapter 2.2). Furthermore, the profit margin for both cases are different. The project can operate with greater efficiency in case II compared with that of case I. Thus, the financial sitution for both cases as regards the impact of CDM can be illustrated in figure-form. Figure 61 and 62 illustrate the impact of CDM on medium scale biogas electricity generation project with case I and II.

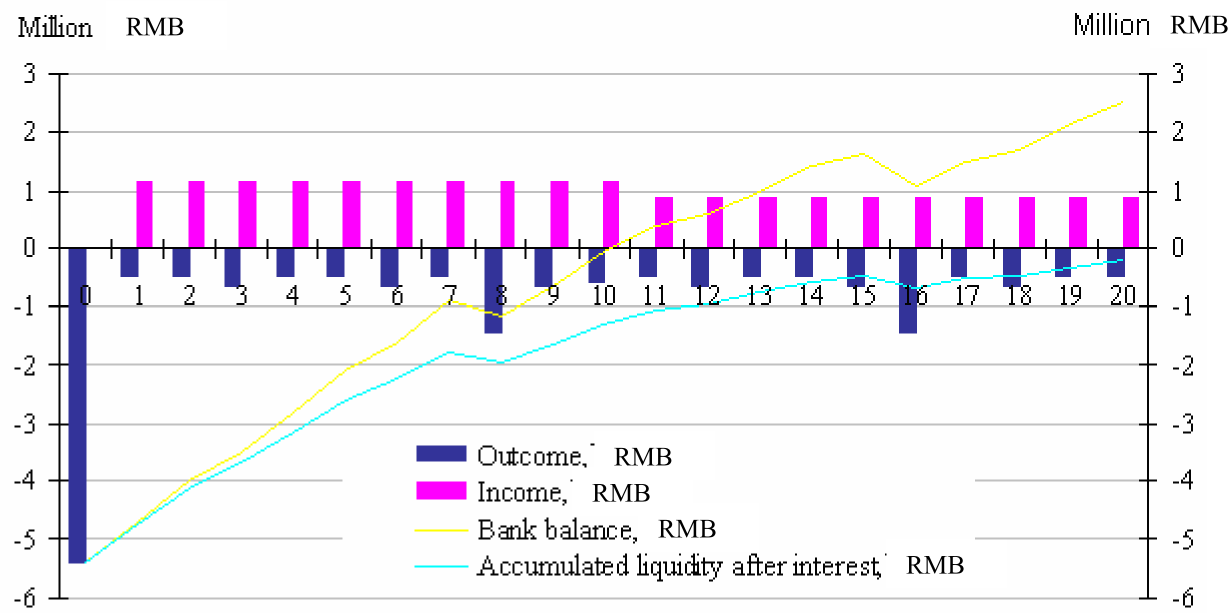
Figure 61: Impact of CDM on medium scale biogas electricity generation project with a bilateral or multilateral approach



Source : Chapter 4.2

The next Figure shows the same information for case II

Figure 62: Impact of CDM on medium scale biogas electricity generation project with unilateral approach



Source : see case II, Table 58

From Figure 61 and 62, with the same amount of investment costs, the cash flow and liquidity situation in case II is much better than case I. Thus, the interest charges and the source of investment play a significant part. The different sources of investment determine the price of carbon dioxide emission reduction. For case II, with the lower interest charges and higher price of carbon dioxide emission reduction, the project owner is already interested in how to make the project profitable.

Nowadays China's biogas electricity project can be implemented, but must face more challenges with the implementation the uniliteral CDM form of finance. In conclusion, the priority and challenges can be presented as follows:

- *National carbon trade organisation unilateral CDM approach* With the development of a CDM biogas project, nowadays, a national carbon trade organisation would be set up with assistance from The United Nations Development Programme (UNDP) (National development nd commission reform, 2008). This is a country's carbon trade organisation, which helps all renewable energy project owners to obtain benefits from CDM project implementation. This organisation places emphasis on premium for the projects to be that of CDM. This is mainly because it is controlled by the National Development and Commission Reform located in Beijing. In the year 2009, a carbon trade agency was also set up in Chengdu city in the south-west of China. The future development of the organisation may result in the implementation of a unilateral CDM project.
- *Mature implementation of bilateral and multilateral CDM form of finance* The carbon trade price is determined by buyers from industrailised countries. With the development of a carbon system based on the Emmssion Reduction Trade (ERT) in European countries, many buyers have joined forces to protest against the increased price of carbon dioxide emission reduction. Moreover, for the multilateral form of implementation, the organisation as third party must be found for carbon trading. In this case, some agencies (for instance: Nethelands carbon trade organisation, The England carbon trade agency, etc) have more experience in the carbon market, and have more contact to buyers and sellers.
- *Reqiurement of financial support from external sources* Some medium and large scale biogas projects need financial support from international organisation to relieve the burden on government or project owner, for instance: The World Bank. In this case, the foreign bank can offer low interest rates for project owners. However, in the case where more foreign banks become buyers or stakeholders for biogas projects, the price will fall sharply .

In the conclusion, the project owner needs to face some kind of risks concerning CDM implementation. These risks are presented below.

- CDM project might face the risk of approval CDM projects must carry out two sets of procedures i.e, domestic and international, depending on approval by a number of organizations. The process of applying for project approval takes about three to six months. For the project to be approved, an amount of 100,000 $ needs to be paid regardless of the outcome for preliminary design, packaging and other input costs. In case one fails to again approval for a project, no response is provided.
- The second risk of CDM is that there is a vicious price competition. CDM is as of now a buyers' market. Enterprises in developing countries hold a weak bargaining position in this context. As we gradually realized from the CDM, more enterprises will enter the market on the supply side. In this case the price for emission reduction will further decrease and the expected earnings will be diminished significantly.
- Thirdly, the risk is that in future policy may change. China as a developing country is not currently required to implement the "Kyoto Protocol" of the emission reduction requirements, but what happens after 2012? With China's economic development and rapid technology innovation, the pressure on emission reduction is on the increase. There is a growing acceptance within China that the country's own population is already facing the consequences of climate change. To overcome this problem it has to be understood as a global challenge requiring the engagement as energy saving, energy security and the environment. The stakes are rising and China itself knows that the country is both on the frontline of the impact of climate change and is to play an important part of potential global solution.

After discussing and analysing the three biogas projects, it would also be interesting to compare them with some German biogas projects. Thus, two points as follows will be compared and discussed. The first point concerns the economy of biogas projects. The second deals with the model of costs of carbon dioxide emissions.

5.2 Economic and ecological aspects concerning German biogas projects

There are two issues raised in this section. These are the comparison of the ecomomy of biogas plants and the results in GHG reduction between Chinese and German biogas projects.

5.2.1 The economical aspects of biogas projects

As Chapter 2 discribed, for China's biogas development, there are more and more medium and large scales biogas projects in operation. Moreover, the Chinese government pay attention to biogas development. Germany already has great experience in the area of biogas development. The amended RESA led to an increase in biogas research. Moreover, both countries have unique characteristic features with respect to biogas project operation.

The costs effectiveness for both Chinese and German biogas projects are different. For Chinese projects, the medium and large scale biogas projects in Chapter 4.2 and 4.3 can be taken as an exmple. The costs and revenue are presented here once more in Table 59 (also compared Chapter 4.2 and 4.3).

Table 59: Review of costs and revenue for medium and large scale biogas plants

Components, RMB/a	Medium scale biogas project①	Large scale biogas project②
Capital costs③	400 328	6 601 367
Operating costs④	426 057	2 531 488
Costs of payment of salaries	30 000	480 000
Substrate costs	0	0
Total annual costs	856 386	9 613 056
Sale of electricity	857 385	10 196 802
Heat production	13 091	829 212
CHPP bonus		
Total revenue	870 476	11 026 014

Source: Chapter 4.2 and 4.3

Notes:

① *See Chapter 4.2*

② *See Chapter 4.3*

③ *The capital costs are separated from interest charges and amortization costs*

④ *The operating costs included costs of reapir, process energy costs, as well s other costs.*

The costs effectiveness can be compared with a German biogas project with a 350 kW_{el} renewable recource plant.

The data for selected two Chinese projects are indicated in Chapter 4.2 and 4.3. For this selected German biogas project, the substrates are from cow-dung and energy crops (sillage of maize and raps, and the like). The investment costs also include 100,000 € (the equivalent to 1,000,000 RMB) from the regional government support in Hessen. Moreover,. the electricity efficiency is 37.1% and that of is thermal energy is 45%. The electricity and heat energy produced are sold to be fed into the national grid. Table 60 shows the data for this project.

Table 60: Project data

Components	Unit	Value
Substrates	t	9,850
Livestock	GV	130
Cow manure	t	4,050
Avaliable cultivated area	ha	180
Renewable resource	t	5,800
Output		
Biogas production	kWh/a	7,189,841
Electricity production	kWh_{el}/a	2,663,836
Heat production	kWh_{th}/a	3,235,400
Electricity for feeding into national grid	kWh_{el}/a	2,663,836
Heat for feeding into national grid	kWh_{th}/a	115,140

Source: Program und Rechtlinen zur Förderung der ländlichen Entwicklung in Hessen, 2007

Thus, this project's material is 4,050 tons cow-dung and 5,800 tons energy crops. The biogas can produce 72 kWh energy annually. The generated electricity and heat are 2.7 kWh_{el}/a and 3.2 kWh_{ther}/a. The total generated electricity and few heat energy are fed into national grid. For this German biogas plant, the data for annual costs and revenue indicated in Table 61. Here the total investment costs are 1,155,000 €, equivalent to 11,550,000 RMB.

Table 61: Annual costs and revenue

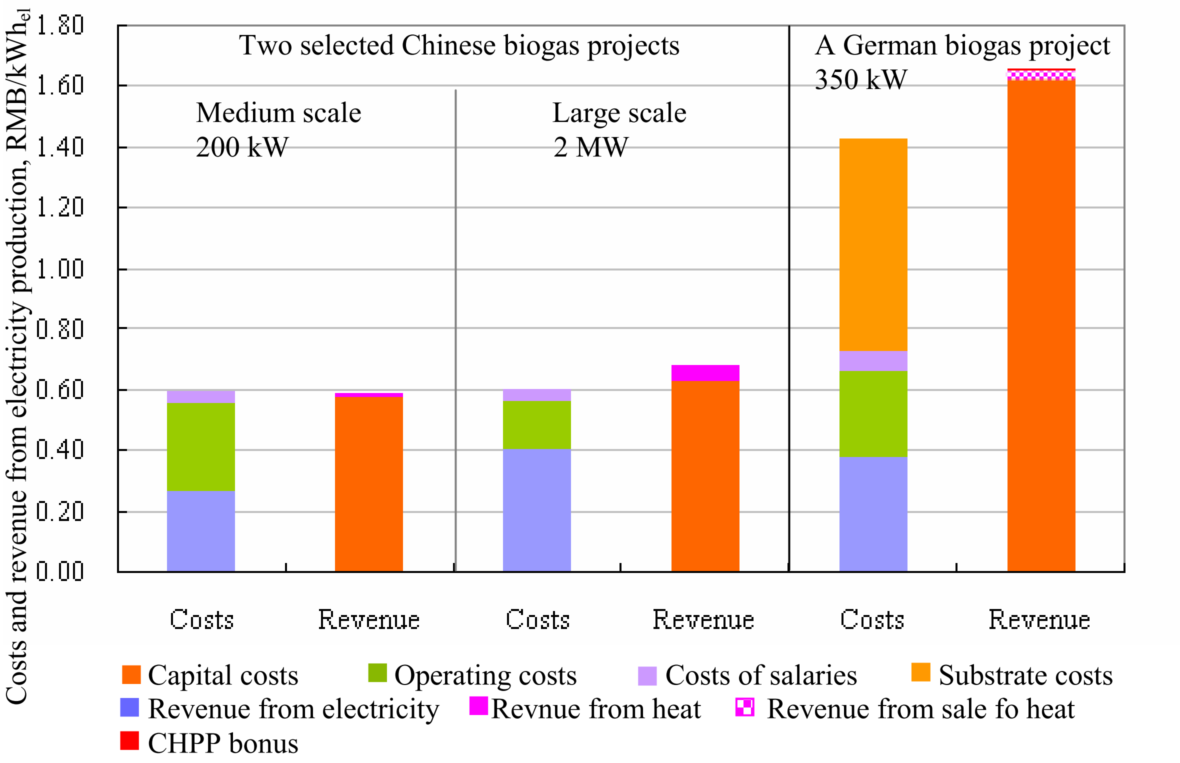
Components, RMB/a	Value
Capital costs	1,016,410
Operating costs	758,230
Costs of payment of salaries	270,380
Substrate costs	1,856,079
Total annual costs	3,910,810
Sale of electricity	4,319,520
Heat production	79,160
CHPP bonus	19,960
Total revenue	4,418,640

Source: Program und Rechtlinen zur Förderung der ländlichen Entwicklung in Hessen, 2007

Thus, all the selected Chinese and German biogas projects operate for electricity and heat generation. For all these three projects are the operated to generate electricity for feeding into national grid. The difference is that produced heat energy is utilized by local companies and farms in two Chinese projects. In this case, the heat energy is not fed into the national gird.

Moreover, the two Chinese projects run 7,500 hours annualy. The German's seleted project run 7,610 hours annually. The comparison for two seleted Chinese projects in this study and a German project is indicated in Figure 63.

Figure 63: Comparison of costs and renuve for Chinese and German projects



Source: Own interpretation base on the data from Chapter 4.2 and 4.3, Table 61

Thus, the comparison can be concluded as follows. The Chinese biogas projects have lower electricity costs than a German project. In this context, the revenue from electricity production is also low. The costs for this German biogas plant are much higher, because substrates are cow-dung and some energy crops. Normally, for the Chinese projects, the substrate costs are free. If a German biogas project is a renewable resource project, then high costs must be considered for cultivation, gains, etc. Moreover, the wages are much lower for Chinese projects compared with that of Germany.

The difference in costs and revenue between Chinese and German projects can be considered. Another difference considered is that of the substrate. Usually, German biogas projects operate with energy crops. Due to the high energy content, it produce more biogas than the same amount of animal waste. The project owner can also obtain a bonus from energy crops utilization. However, it is forbidden to use any kind of energy crop for China's biogas projects. The reason is that China is a developing country with the largest population in the world. In this context, the man land ratio tends to be very low.

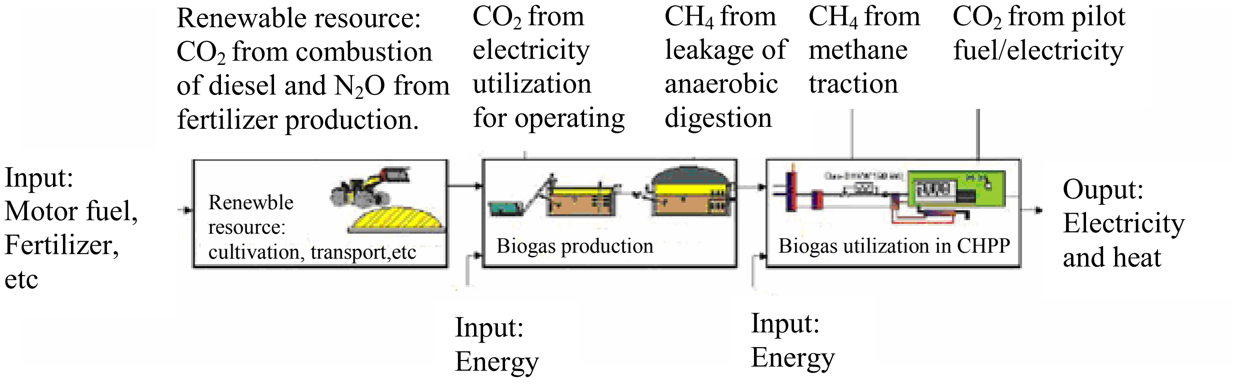
Moreover, the reason for the difference between Chinese and German biogas projects could also be linked to that of electricity efficiency, as well as the price of electricity. For the Chinese medium scale project, the electricity efficiency was 30%. Contrast this to the selected German project, this was 37%. Moreover, with German biogas projects, the basic bonus is about 10 cent/kWh$_{el}$ (see Chapter 2.2). This kind of bonus facility is not available in China. Furthermore, the heat energy produced can only be used locally in China. For the German project, the heat produced can also be fed into the national grid. In this context, farmers qualify to obtain CHPP bonus.

Although the context for biogas development in both China and Germany are different, China has the opportunity to learn from the German experience for its own development. The difference in ecological aspects concerning the methodology for carbon dioxide emissions is discussed in the next section.

5.2.2 The methodology concerning the ecological aspects of carbon dioxide emissions

Biogas projects result in the reduction of carbon dioxde emissions. For example, due to the difference in substrate and energy utilization, the results of carbon dioxide are also different. Usually, the substrate for Chinese biogas projects are animal waste. To analyse carbon dioxide emission, the methodology associated with CDM is introduced in Chapter 3.2. Normally, due to the use of energy crops as substrate for biogas production in German biogas plants, the methodology for greenhouse emission estimation might vary. Figure 64 shows the procedure for GHG emissions of rural biogas production.

Figure 64: Procedure of GHG emissions of rural German biogas production



Source: Biogas forum, 2009

Compared with GHG emissions for Chinese biogas projects, the GHG emissions must be estimate considering renewable resource preparation in Germany. The reason being, the use of energy crops mainly as substrates for biogas production in most German biogas plants. Thus, by German standards, the procedure, for the carbon dioxide emission reduction can be considered in this form:

$$ER_y = E_{FE} - E_{BP}$$

Source: WBA, 2007

Notes:

$$E_{BP} = E_{BPtotal} - E_{Aanimal} - E_{Sfh} - E_{Ala}$$

ER_y *: Emission reduction*

E_{FE}*: Emissions from preparation of electricity from fossil fules*

E_{BP}*: Emissions from preparation of biogas production*

$E_{BP.total}$*: Emissions from total biogas electricity production*

E_{Aaniml}*: Advoided methane emissions in livestock*

E_{Sfh}*: Emissions from fossil fuels substituted for heat utilization*

E_{Ala}*: Advoided emissions from land application*

Concerning the above calculation, the description of the methodology for GHG is different. The difference can be considered based on the different lines of thought. This study used the methodology for GHG calculation, based on UNFCCC. This methodology is based on GHG emission reductions from manure management system. Compared to Chinese projects, the selected German biogas electricity project used the methodology developed from German research institutes. Thus, the difference in these two methodologies is indicated in Table 62.

Table 62: Difference between the methodologies of UNFCCC and that of German institutes

	BE_y / E_{FE}	$PE_y / E_{BPtotal}$	LE_y / E_{BP}	ER_y
UNFCCC	BE_{CH_4} BE_{N_2O} $BE_{el/heat}$	$PE_{AD} + PE_{Aer}$ PE_{N_2O} $PE_{PL} + PE_{flare} + PE_{el/heat}$	$LE_{P,N_2O} - LE_{B,N_2O}$ $LE_{P,CH_4} - LE_{B,CH_4}$	$ER_y =$ $BE - PE - LE$
German institutes	E_{FE}	$E_{BPtotal}$	$E_{Aanimal}$ E_{Sfhl} E_{Ala}	$ER_y =$ $E_{FE} - E_{BPtotal} - E_{Aanimal} - E_{Sfhl} - E_{Ala}$

Source: UNFCCC, 2008 and WBA, 2007

Compared with the two methodologies in Table 62, for the first group (BE / E_{FE}), from the methodology developed by UNFCCC, the CH_4 and N_2O emissions from AWMS are considered, as well as the carbon dioxide emissions from electricity and heat use. In this context, only one factor is considered . This refers to the emissions from the electricity generated from fossil fuels.

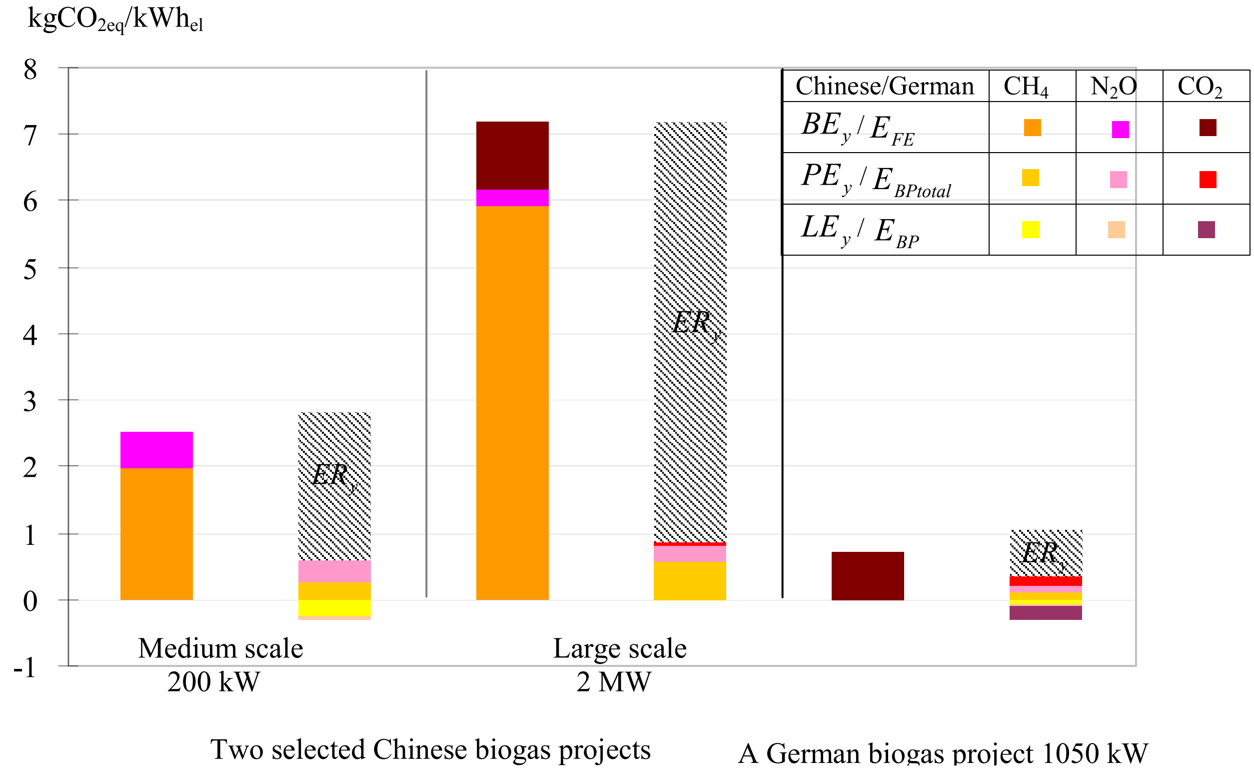
Next group is with ($PE_y / E_{BPtotal}$). There are more factors that should be considered from the methodology developed by UNFCCC. In this context, the CH_4 emissions from leakage that captures CH_4 and also aerobic treatment of animal waste must be calculated, as well as the N_2O emissions from AWMS. Moreover, in some cases, the leakage of emissions should be considered in addition to that from the use of electricity and heat. Compared with PE_y , the factor of $E_{BPtotal}$ from German institutes includes emissions from biomass cultivation, transport, storage of biomass, conversion of biomass for biogas electricity, as well as storage of fertilizer.

Furthermore, considering the methodology developed by UNFCCC, the leakage of CH_4 emissions and N_2O emissions for arable farming constituting the project activity and baseline scenario must be calculated. In the case of the German example, there is the need to avoid CH_4 emissions in livestock. Substituting energy from fossil fuels for heat utilization must be considered in addition to advoiding CO_2 emissions for arable farming.

Thus, for both methodologies, the emission reductions are different due to previous factors. The methodlogy developed by the German institutes avoided CH_4 emissions in livestock ($E_{Aanimal}$). This is thus the difference between the CH_4 emissions from the baseline scenario and that of project activity. It is, however, interesting to note that the CH_4 emissions from baseline scenario and that of project activity are from the UNFCCC.. The case is the same as that, substituted heat utilization from fossile fuels (E_{Sfhl}). The advoided emissions from land application (E_{Ala}) can also be compared with the leakage of nitrous oxide emissions between project activity and baseline scenario.

In order to better undertand the difference between the two methodologies, there is an example of GHG estimation. The result of selected Chinese biogas projects in Chapters 4.2 and 4.3 are used as a reference. Moreover, the results of a German biogas electricity project with 1,050 kW_{el} is also considered as a source of reference. The difference is also in the substrates. Two Chinese biogas projects utilized 100% animal waste. The substrates from German biogas project are mixed (see Chapter 5.2.1). In view of this, 62% of total dry matter for substrates come from a mixture of some energy crops and cow-dung. The emissions and emission reduction from the three projects are shown in Figure 65.

Figure 65: GHG emissions and emission reduction for selected Chinese projects and a German project



In the Figure 65, the emission reduction is higher in the two Chinese projects compared with that for the German project. The reason is that the animal waste used as substrate produces a large amount of GHG. This is the case especially for large scale biogas project with 2 MW. Moreover, for the large scale Chinese biogas project, there is no leakages for arable farming. The resaon is that the biogas residue produced will be processed for fertilizer (see Chapter 4.3). The fertilizer-producing factory is located in the same area as the project site.

Furthermore, comparing the results from Chinese and German biogas projects concerning their methodologies used, it must be noted that the two Chinese projects used fodder for livestock derived from arable farming. The cultivation areas are located nearby the project sites for both projects (see Chapter 4.2 nd 4.3). However, the methodology developed by UNFCCC does not explain the procedure for computation for emissions from fodder, its cultivation and harvest, as well as the storage. Moreover, for this large scale Chinese project, the biogas residue produced is used as fodder for livestock. Regarding project plan, the bio-residue could be used for organic fertilizer production in the future. In the case of organic fertilizer production, the emissions must be also considered. In China, most biogas projects produce fertilizer from bio-residue. This may increase project owner's income. Concerning emissions from fertilizer/fodder production, these two approaches are neither those used by UNFCCC nor by German institutes.

6 Summary

"Garbage is misplaced treasures." Today, people use animal waste to produce by means of biogas process electricity and heat, as well as a substitute for substituted fossil fuels. Biogas development is one of China's business booms in resent years. Concerning the situation of China's rural areas, livestock in rural household and livestock farms result in the generation of a larger amount of manure. The use of animal waste from livestock in rural households and livestock farms to produce electricity and /or thermal energy can lead to economic and ecological benefits. Moreover, with the CDM project implementation, the project owner can obtain more economic benefit from ecological protection. This study gives an overview of current problem statement, presents the methodologies, makes the economic and ecological analyses for three selected projects, discusses the results, as well as comparing Chinese and German biogas projects.

The problem statement identified four key issues.. These include difficulty of biogas project implementation, lack of technical know how in biogas utilization, lack of financial support, insufficient project plan, as well as less influence on the carbon market (see Chapter 1.1). The aims of the study (see Chapter 1.2) as well as the structure of the dissertation are also presented (see Chapter 1.3).

The literature review and background to the study are in the second chapter. The general biogas development and utilization for China and Germany are presented. There are some biogas technologies currently being used in China. These include one household one tank technology (project 1), medium scale biogas project with electricity generation (project 2), as well as large scale biogas project with electricity generation for feeding into the national grid (project 3). For biogas utilization in Germany, the development considering the promulgation and amendment of RESA is also presented (see Chapter 2.1). Moreover, the Kyoto Protocol and CDM are the key points in this Chapter. The CDM project activities with different types of renewable energy projects are also described (see Chapter 2.2).

Many methodologies are used for analysis in this study. The methodologies used for economic analysis include the cost-revenue, sensitivity analysis, Break-even analysis and "worst, normal and best cases analysis". The cash flow and liquidity and Monte-Carlo-

Simulation are also included. The CDM approach is the criteria used for environmental analysis (see Chapter 3).

The economic and ecological analyses for three selected biogas projects are made in Chapter 4. The household biogas project is the first project. This project has good financial support from the Chinese governmental and The World Bank. First, the costs-revenue analysis is for this project considering the farmers' share of investment. The same analysis also made for the same project with total costs of investment. The benefit of thermal energy utilization is analysed for substituted coal. Moreover, this is a first CDM project with the price of 10 $/tCO_{2e}$. The results of this project can be summarised as follows: in the view of economic benefits, the farmers obtain benefit from biogas utilization substituted for coal consumption. Moreover, household projects need financial support from government. In addition to this, without CDM benefit the project cannot be operated. For the ecological aspect, a large amount of GHG reduced. In this case, coal as a GHG emission producer for household, substituted by biogas, results in GHG emission reduction. Household can also use clean energy (biogas) to cook and heat, so that relieve of suffering for coal pollution (see Chapter 4.1).

The economic and ecological analyses are also made for medium scale biogas electricity production project. This project is totally financed by the project owner. In this project, two scenarios are analysed. The first is 20% animal waste from total waste produced and used to generate biogas. In this case, the generated biogas electricity is used by the local company and dairy-farm. The second scenario deals with biogas electricity production with 100% animal waste. The generated electricity in this case is fed into the national grid. In regard of economic aspect, with the total different investment costs and bonus requirement, the project operates more successfully in the case of Scenario II than Scenario I. However, the different results from other projects concerning Scenarios I and II with under the same conditions might also be vary. Moreover, the project for both scenarios is considered a CDM project with the price of 10 $/tCO_{2e}$. The cash flow analysis shows the project with CDM under condition of both scenarios is unprofitable. In this case, the project with Scenario II is better than Scenario I. From ecological point of view, a meaningful contribution to the energy supply also made from biogas for this project. Moreover, biogas results not only in substitution of coal as a fossil energy utilized for farm before, but also in GHG emission reduction for animal waste disposal and electricity and heat production, as well as also fertilizer utilization for two scenarios (see Chapter 4.2).

The large scale biogas electricity production project for feeding into the national grid is the final project in this study. This project is a key project in China. There are also two scenarios for this project. The first Scenario is the project operated with the national technology of CHPP. The project with second scenario operates with CHPP from Austria. On the side of economic aspect, it must be noted that the investment costs for both scenarios are different, but the bonus requirement and price for sale of electricity are the same. In this case, the large scale biogas electricity projects can operate better when the electricity efficiency from CHPP is high. Moreover, the project also applied for consideration as a CDM project. With the assumed price of 10 $\$/tCO_{2e}$, the project owner can obtain more profit in both scenarios. In terms of ecological aspect, a major benefit for the use of biogas is also its ecological advantage. This chapter also compared the ecological impact of different two scenarios, resulting in electricity and heat on the project site. Thus, the ecological analyses involving in estimation of carbon dioxide emissions and emission reduction also presented.

In the Chapter 5, some key points are discussed concerning the economic and ecological analyses for three selected projects. Moreover, the comparison with the German biogas project example is presented. The first concerns the project background. Furthermore, the project background might also have an influence on the larger scale biogas electricity generation project. But the same type of project may generate different effects considering the project site and situation (see Chapter 5.1.1).

Next, the bonus from the government plays a very important role for any biogas project development in China. In this context, the following possible further bonuses are discussed. These are, bonuses for national technology utilization, animal waste discharge from other locations, that for west-middle area, as well as the project with "key point" (see Chapter 5.1.2).

Then, one important point concerning impact of CDM is also discussed. Due to different forms of finance for CDM project implementation, the project can have different effects. Furthermore, some risks are also discussed. However, the CDM in China must face the following challenges: the long-term CDM project application, the carbon market belonging to developed countries, as well as future policy changes (see Chapter 5.1.3).

The comparison for economic and ecological analyses between the Chinese and German biogas projects are presented in the last section of this study. In this context, two previously analysed Chinese biogas electricity projects are compared with a German biogas electricity project (see Chapter 5.2.1).

The methodologies used in both countries concerning ecological aspects of GHG emission reduction are also a bit different. Apart from that, the difference in approach is evidence in the procedure for calculation. The flaws encountered application of both methodologies are discussed (see Chapter 5.2.2).

Summarising the economic and ecological aspects of biogas scene in China, the following points should be noted: biogas as one of the most popular renewable energies, which has already prosperous development for both households and livestock farms. The Chinese government pays attention to the biogas utilization and GHG emission reduction by constantly amending of REL and raising of amount of bonus. As a part of these measures, more and more coorperation between governments and international enterprises concerned with financial and technical issues has also been developed. Thus, the study for both economic and ecological benefits has “epoch-making” significance.

7 Literature

Anton J. and Diner C. (2005): Can Risk Reducing Policies Reduce Farmer's Risk and Improve Their Welfare? 11th Congress of the European Association of Agricultural Economists, 24.-27. August 2005, Kopenhagen.

Bahrs, E. (2002) Methoden des Rechnungswesens als Instrumente des Risikomanagements in der Landwirtschaft. In: BROCKMEIER, M. et al. (Hrsg.): Liberalisierung des Weltagrarhandels –Strategien und Konzepte. Landwirtschaftsverlag Münster- Hiltrup, 255-264

Besgen, S., K. Kempkens (2007). Energy and Substance Conversion in Biogas plants - Results of measurement investigations of agricultural biogas plants in the Rheinland region. Agrartechnische Forschung-Agricultural Engineering Research **13**(3): 57-66.

Bhattacharya, S.C. and Salam, A.P. (2002). Low greenhouse gas biomass options for cooking in the developing countries. Biomass and Energy 22, 305-317.

BioenergyGermany (2008). The process of biogas generation and transmission. www.bioenergygermany.net.

Biogas from Excreta (2002). Treatment of Faecal Sludge in Developing Countries.

Bureau of Commerce of Luzhuo City, 2006.

BMU-Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Hrsg.) (2009): Biogas und Umwelt. Berlin.

BMU (2003): EEG-Novelle: Entwicklung der Stromerzeugung aus Erneuerbaren Energien und finanzielle Auswirkungen, Berlin.

BMU (2008): EEG-Novelle: Vergütungssätze und Degressionsbeispiele nach dem neuen Erneuerbare-Energien-Gesetz (EEG) vom 31. Oktober 2008.

Bundesministerium für Verbraucherschutz, Ernährung und Landwirtschaft, 2005.

CDM in China, 2009.

CDM pipeline statistic, 1 January 2009.

Chen, Rongjun. (1997). Livestock-biogas-fruit systems in South China. Ecological Engineering 8: 19-29.

Chen, Z. J. (1987). Biogas Development in China. Poultry Science **66**(6): 951-953.

Chen R. (1997). Livestock biogas fruit system in South China. Ecological Engineering 8 (1):19-29.

China Coal Information Institute (2004). Investment Guide for China CMM/CBM.

China new energy information, Beijing, 2007.

China Economic Review, "the environment – a great green wall" 26 July 2001.

Converse, James, C. (2001), "Fundamentals of Biogas Production from Dairy Manure" Presentation to the Wisconsin ad hoc Anaerobic Digestion Committee Meeting. www.mrec.org/pubs/ bio_gas_production_from_dairy_manure.pdf

Dachverband Agrarforschung (2006): Energie aus Biomasse - weltwirtschaftliche, ressourcenökonomische und produktionstechnische Perspektiven. http://daf.zadi.de.

Delhotal, K.C. (2006): Mitigation of Methane and Nitrous Oxide Emissions from Waste, Energy and Industry, The Energy Journal, Multi-Greenhouse Gas Mitigation and Climate Policy, Special Issue 3, 45-62.

El-Mashad, H. M. and Zhang, R.H. (2007). Co-digestion of food waste and dairy manure for biogas production. Transactions of the Asabe **50**(5): 1815-1822.

Fachagentur Nachwachsende Rohstoffe (Hrsg.) (2004): Handreichung Biogasgewinnung und –nutzung; erstellt von: Institut für Energetik und Umwelt, Bundesforschungsanstalt für Landwirtschaft, Kuratorium für Technik und Bauwesen in der Landwirtschaft e. V.; Gülzow.

FNR (2004): Handreichung Biogasgewinnung und -nutzung, Fachagentur Nachwachsende Rohstoffe, Gülzow.

Friedrichs, Georg (2005): Einspeisung von Biogas in das öffentliche Gasnetz –Anforderungen und Chancen; Energy.

Frühwirth, R. and Regler, M.(1983): Monte-Carlo-Methoden. BI Wissenschaftsverlag, Zürich.

Han, J., Mo A., Lu, Y., Zhang, L. (2008) Smallscale bioenergy projects in rural China: Lessons to be learnt; Energy Policy 36 2154–2162.

Hashimoto, A.G. and J. Steed. (1992). Methane Emissions from Typical Manure Management Systems. Oregon State University, Corvallis, OR.

Heissenhuber, A (2007). Economic and ecological aspects of bioenergy production. Lohmann Information 43 (1): 24-30.

Hornbachner D.; Hutter, G.; Moor, D.(2005) Biogas-Netzeinspeisung – Rechtliche, wirtschaftliche und technische Voraussetzungen in Österreich; Berichte aus Energie und Umweltforschung; Bundesministerium für Verkehr, Innovation und Technologie Österreich; 19

Hubei Statistics Bureau (2006). A household biogas project, Hubei.

IGES (2005). CDM Country Guide for India.

Institute for Global Environmental Strategies (Ed): CDM Country Guide for China, Beijing, 2006.

Institut für Energetik und Umwelt GmbH. (2005): Nachhaltige Biomassenutzungsstrategien im europäischen Kontext; Leipzig.

International Conference on Renewable Energy (2004). CDM and JI, Bonn, 2004.

IPCC (2007): Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

IPCC (2007a): Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2007b): Summary for Policymakers. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2007c): Agriculture. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC (2007d): Waste Management. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jakeman, G., Fisher, B.S.,(2006): Benefits of Multi-Gas Mitigation: An Application of the

Global Trade and Environment Model (GTEM), The Energy Journal, Multi- Greenhouse Gas Mitigation and Climate Policy, Special Issue 3, 323-342.

Johnson, J.M.-F. (2007): Agricultural opportunities to mitigate greenhouse gas emissions, Environmental Pollution **150**, 107-124.

Kemfert, C. (2006): Economic Impact Assessment of Climate Change – A Multi-gas Investigation with WIAGEM-GTAPEL-ICM, The Energy Journal, Multi-Greenhouse Gas Mitigation and Climate Policy, Special Issue 3, 441-460.

Kobzar, O. A. (2006). Whole-farm risk management in arable farming: portfolio methods for farm specific business analysis and planning. PhD Thesis. Wageningen University.

Kocak-Enturk, E., K. Yetilmezsoy (2007). A small-scale biogas digester model for hen manure treatment: Evaluation and suggestions. Fresenius Environmental Bulletin **16**(7): 804-811.

KTBL, (Hrsg.) (2004): Betriebsplanung Landwirtschaft 2004/2005. 19. Auflage, Darmstadt.

KTBL, (2006). Kuratorium für Technik und Bauwesen in der Landwirtschaft, Gasausbeute in landwirtschaftlichen Biogasanlagen, KTBL-Schriften-Vertrieb im Landwirtschaftsverlag GmbH, Münster, Germany.

Kyoto Protocol, 2007.

Kyoto University: Comprehensive Analysis and Evaluation of CDM Projects in China, Kyoto, 2006.

LFL (2006a): Biogasausbeuten verschiedener Substrate. http://www.lfl.bayern.de/ilb/technik/10225/ (Abrufdatum: 24.03.2006).

Li, Kangmin (2006). Biogas China. Institute of Science in Society. [Online]. Available. http://www.i-sis.org.uk/BiogasChina.php.

Li, Peter J. (2005). "China's animal farming industry: Current state and future directions." A Compassion in World Farming Trust and Humane Society International-sponsored Report, 12.
Li Z, Tang R, Xia C, Luo H, Zhong H (2005). Towards green rural energy in Yunnan, China; Renewable Energy 30 99–108.

Liu Yu, Kuang Yaoqiu, Huang Ningsheng (2008). Rural biogas development and greenhouse gas emission mitigation. China Population, Resources and environment. 18(3):48-53.

Liua G, Lucas M, Shen L (2008); Rural household energy consumption and its impacts on ecoenvironment in Tibet: Taking Taktse county as an example ; Renewable and Sustainable Energy Reviews 12: 1890–1908.

Luo, Shiming (2009) Agricultural Ecology, Beijing: China Agriculture Press, pp360.

Lusk, P.(2004) "Methane Recovery from Methane Recovery from Animal Manures The Current Opportunities Casebook.". National Renewable Energy Laboratory, U.S. Department of Energy, Managed by Midwest Research Institute for the U.S. Department of Energy under contract No. DE-AC36-83CH10093.

Ma, J. (2002). Spatial Analysis of the Potential for Dairy Manure as a Renewable Energy Resource in New York State. M.S. Thesis in Biological and Environmental Engineering. Cornell Univeristy, Ithaca, NY.

Maeng H, Lund H. (1999). Biogas plants in Denmark: technological and economic developments. Applied Energy;64:195–206.

Mears, D. (2001). Biogas Applications for Large Dairy Operations: Alternatives to Conventional Engine-Generators. Prepared under contract to Cornell Cooperative Extension Association of Wyoming County, Warsaw, NY. Final Edition.

Methane to Markets (2008): Global Methane Emissions and Mitigation Opportunities. Fact sheet, www.methanetomarkets.org

Ministry of Agriculture (MOA): Biogas household digester, 2000.

Ministry of Agriculture (MOA) (Ed): The Clean Development Mechanism- An Assessment of Progress, Beijing 2006a.

Ministry of Agriculture (MOA) (Ed.): Project Design Document of Ecotype for Co.Ltd, Beijing, 2006b.

Ministry of Agriculture (MOA) (Ed.): Renewable Energy Law, Beijing 2008.

NDRC (2003). Country communication report.

NDRC (2009). China-EU CDM Project, Beijing.

Oregon Office of Energy (2000), "Anaerobic Digester At Craven Farms: A Case Study", http://www.energy.state.or.us/biomass/Digester/craven.htm.

Price, E., Cheremisinoff, P. (1981). Biogas Production and Utilization. Ann Arbor: Ann Arbor Science Publishers.

Rauh, S., Berenz, S. und Heissenhuber, A. (2008). Abschätzung des Risikos beim Betrieb einer Biogasanlage mit Hilfe der Monte-Carlo-Methode. Schriften der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V., Band 43.

Richardson, J.W., Schumann, K. and Feldman, P., (2006). Simetar: Simulation for excel to analyze risk. Department of Agricultural economics, Texas A&M University.

Roos K.F. and Moser M.A. (1997b). AgSTAR Handbook A Manual For Developing Biogas Systems at Commercial Farms in the United States. Washington, DC, EPA 430-B97-015.

Rural Energy Development in China, Dept. of Environment and Energy, Ministry of Agriculture, 1994.

Shi, Dinghuan (2000). "China's Tenth Five-Year Plan: On renewable energy research and development", Chinese Ministry of Science and Technology, presentation to the US-China Renewable Energy Forum, Washington, DC, April.

Su, J.J., B.Y. Liu, and Y.C. Chang. (2003). "Emission of greenhouse gas from livestock waste and wastewater treatment in Taiwan." Agriculture, Ecosystems and Environment 95: 253-263

UNFCCC, 2008.

UNFCCC CDM Executive Board (EB). 2002. Initial administration fee at registration stage ("registration fee"). EB 6, report, annex 5 (October 24, 2002).
———. 2004a. Indicative simplified baseline and monitoring methodologies for selected small-scale CDM project activity categories. Appendix B of the simplified modalities and procedures for small-scale CDM project activities. EB 7, report, annex 6 (October 24, 2004).
———. 2005b. Guidelines for completing the project design document (CDM-PDD), the proposed new methodology: baseline (CDM-NMB) and the proposed new methodology: monitoring (CDM-NMM). ver. 4.

Urmee T, Harries D, Schlapfer A (2009). Issues related to rural electrification using renewable energy in developing countries of Asia and Pacific ; Renewable Energy 34 354–357.

Vanburen, E. A. (1980). Biogas Beyond China - 1st International Training-Program for Developing-Countries. Ambio **9**(1): 10-15.

Wang, M. (2002). Biogas Technology And Ecological Environment Development In Rural Areas Of China Chinese Academy of Agriculture Engineering Research http://ecosanres.org.

Wang, X.H. and Li, J.F. (2005). Influence of using household biogas digesters on household energy consumption in rural areas - a case study in Lianshui County in China. Renewable & Sustainable Energy Reviews 9 (2): 229-236.

Wu C. The current state of rice holls gasification and power generation in China. China-EU Renewable Energy Technology Conference. Sep. 1997, Beijing China.

Wu Y. (1987). Biogas Newsleter by Biogas Assoc. Sichuan Province.

Xu Guan Hua (Vice Minister Chinese Ministry of Science and Technology), (2000). Presentation to the US-China Renewable Energy Forum, Washington, DC, April.

Yua, L, Yaoqiua, K, Ningshenga, H, Zhifenga, W, Lianzhong, X (2008). Popularizing household scale biogas digesters for rural sustainable energy development and greenhouse gas mitigation. Renewable Energy 33: 2027–2035.

Yu, L., K. Yaoqiu (2008). Popularizing household-scale biogas digesters for rural sustainable energy development and greenhouse gas mitigation. Renewable Energy **33**(9): 2027-2035.

Zhang Peidong, Li Xinrong, Yang Yan, Zheng Yonghong, Wang Lisheng (2008). Greenhouse gas mitigation benefits of large and middle-scale biogas project in China. Transactions of the CSAE, 24(9):239-242.

Zhang, Qingfeng; Watanabe, Makiko and Lin, Tun (2010). Rural biomass energy 2020: People's Republic of China. Asian Development Bank, MPRA Paper No. 24987, posted 14. September 2010.

Zhao, X.H. (1985) In: Anaerobic Digestion 1985. China State Biogas Assoc., Beijing, China, pp. 701-710.

8 Annex

Annex I

Annex I-1 Biogas production, thermal value and coal consumption by eight cities and counties in Enshi administrative region in Hubei province.

County/ city	Number of digesters				Biogas production①/m^3	Thermal value②,kWh	Coal consumption③, kg
	8 m^3	10 m^3	12 m^3	15 m^3			
Enshi	1,918	2,412			2,052,128	114,098,317	2,703,752
Jianshi	540	4,030			2,320,240	129,005,344	3,056,999
Badong	1,581	2,989			2,211,976	122,985,866	2,914,357
Lichuan	3,043	2,917			2,782,728	154,719,677	3,666,343
Xuan'en		1,833	1,167		1,681,368	93,484,061	2,215,262
Xianfeng				4,570	4,935,600	274,419,360	4,696,487
Laifeng	3,000				1,248,000	69,388,800	1,644,284
Hefeng			3,000		1,872,000	104,083,200	2,466,426

Notes:

① *Biogas production per cubit meter digester equals to 52* m^3

② *Thermal value of biogas equals to 5.56* kWh_{th}/m^3

③ *Thermal value from coal consumption equals to 4.22* kWh_{th}/kg

Annex I-2 Sensitivity analysis: Thermal energy production costs change depending on cost factors

Costs change depending on	The change of costs of thermal energy production						
	70%	80%	90%	100%	110%	120%	130%
Investment costs	----	----	0.170	0.187	0.205	----	----
Amortization costs	----	0.202	0.193	0.187	0.182	0.178	----
Interest charges	----	0.179	0.183	0.187	0.191	0.195	----
Costs of repair	0.174	0.179	0.183	0.187	0.192	0.196	0.20
Substrates costs	0.183	0.184	0.186	0.187	0.189	0.191	0.192

Notes:

The costs of thermal energy production for total households with digester sizes equals to thermal energy production for each of digester size (see table 18) multiply total number of digesters (see table 11)

Annex I-3 "Worst", "normal" and "best" cases depending on costs for thermal energy production

Digester size, m^3	Type of the costs	Costs, RMB	Revenue,RMB	Costs, RMB	Revenue,RMB	Costs, RMB	Revenue,RMB
8	Fixed①	2308	853	1223	1660	850	1919
	Variable②	1806		961		627	
10	Fixed	2940	1184	1520	2324	1381	2689
	Variable	2297		1223		798	
12	Fixed	764	345	395	681	294	788
	Variable	612		326		212	
15	Fixed	606	375	323	745	231	863
	Variable	606		323		231	

Annex I-4 Methane emission factor and average of swine population

County/city	EF_i ① kg/CH_4/swine/a	Average of swine population before digesters installation			
		8 m^3	10 m^3	12 m^3	15 m^3
Enshi	6.81	4.3	4.7		
Jianshi	6.17	4.1	4.3		
Badong	6.81	4.4	4.8		
Lichuan	4.68	4.4	4.6		
Xuan’en	6.17		4.6	5.1	
Xianfeng	6.17				5.9
Laifeng	6.17	4.3			
Hefeng	6.17			4.8	

Notes:

$$^{①}EF_i = (VS * 365) * \left[B_o * D_{CH_4} * \sum_j \frac{MCF_{ij}}{100} * MS_{ij}\% \right]$$

EF_i *is the methane emission factor for deep pit swine manure management in county I, kgCH*$_4$*/swine/a.*

VS *is the daily volatile solid excreted for swine, which required 0.3kg of dry matter/swine/day;*

Bo *is the maximum methane producing capacity for manure produced by swine, which required 0.29m*^{3}*CH*$_4$*/kgVS (from 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 and Chapter 10);*

D_{CH_4} *is methane density (0.00067 t/m*^{3} *at room temperature 20°C and 1 atm pressure);*

MCF_{ij} *is the methane conversion factor for deep pit manure management system under the value of 32% for Enshi and Badong, 22% for Lichuan, 29% for others (from 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 and Chapter 10);*

MS_{ij} *is the fraction of swine handeld in system j, required to 100%.*

Annex I-5 Baseline methane emissions from AWMS

County/city	Baseline CH_4 emission from manure management system tCO_2/a			
	8 m^3	10 m^3	12 m^3	15 m^3
Enshi	0.61	0.67		
Jianshi	0.53	0.56		
Badong	0.63	0.69		
Lichuan	0.43	0.45		
Xuan'en		0.60	0.66	
Xianfeng				0.76
Laifeng	0.56			
Hefeng			0.62	

Note

$$BE_{CH_4,j,k} = GWP_{CH_4} * \frac{1}{1000} * LN_{i,k} * EF_i$$

Where,

$BE_{CH_4,j,k}$ is the baseline methane emissions from deep pit manure management system

GWP_{CH_4} is the Global Warming Potential of methane, required to 21

$LN_{i,k}$ is the average swine population for household before biogas digesters installation

Annex I-6 Average of coal consumption before digesters installation

County/city	Average of coal consumption before digesters installation, t/household/a			
	8 m^3	10 m^3	12 m^3	15 m^3
Enshi	1.416	1.442		
Jianshi	1.460	1.498		
Badong	1.387	1.337		
Lichuan	1.453	1.492		
Xuan'en		1.457	1.504	
Xianfeng				1.589
Laifeng	1.296			
Hefeng			1.675	

Source: UNFCCC, 2009

Annex I-7 Baseline carbon dioxide emissions from coal consumption

County/city	Baseline CO_2 emission from coal consumption, tCO_2/a			
	8 m^3	10 m^3	12 m^3	15 m^3
Enshi	2.80	2.86		
Jianshi	2.89	2.97		
Badong	2.75	2.65		
Lichuan	2.88	2.95		
Xuan’en		2.88	2.98	
Xianfeng				3.15
Laifeng	2.57			
Hefeng			3.32	

Note:

Baseline CO_2 emission from coal consumption can be calculated as the emission factor multiplies average of coal consumption before digesters installed. Here, the emission factor from combustion of coal can be considered as the formula:

$$EF_{cc} = EF_{rawcoal} * C_{nv} * 44/12,$$

where,

EF_{cc} *is the emissions factor of coal combustion*

$EF_{rawcoal}$ *is 25.8 tC/TJ*

C_{nv} *is the Net calorific value, equals to 20908 kJ/kg*

44/12 is the ratio of the molecular weight ratio of carbon dioxide to carbon is 44/12

Annex I-8 Total baseline emissions

County/city	Total baseline emissions, tCO_2/a				
	8 m^3	10 m^3	12 m^3	15 m^3	Total
Enshi	6,557	8,507			15,064
Jianshi	1,848	14,198			16,046
Badong	5,336	9,964			15,300
Lichuan	10,070	9,936			20,007
Xuan’en		6,380	4246	17,871	10,627
Xianfeng					17,872
Laifeng	9,370				9,370
Hefeng			11,815		11,815
Total	33,181	48,987	16,061	17,871	116,101

Note

The total baseline emissions equal to baseline emissions for each of household multiply household digester numbers (see table 11 and 22)

Annex I-9 Average of coal consumption after digesters installation

County/city	Average of coal consumption after digesters installation, t/household/a			
	8 m^3	10 m^3	12 m^3	15 m^3
Enshi	0.809	0.710		
Jianshi	0.827	0.785		
Badong	0.728	0.614		
Lichuan	0.843	0.771		
Xuan’en		0.770	0.740	
Xianfeng				0.811
Laifeng	0.610			
Hefeng			0.926	

Source: UNFCCC, 2009

Annex I-10 Project methane liquidity from each of household digester

County/city	Project CH_4 emissions from each of household digester, tCO_2/a			
	8 m^3	10 m^3	12 m^3	15 m^3
Enshi	0.20	0.21		
Jianshi	0.19	0.20		
Badong	0.20	0.22		
Lichuan	0.20	0.21		
Xuan'en		0.21	0.23	
Xianfeng				0.27
Laifeng	0.20			
Hefeng			0.22	

Source: UNFCCC, 2009

Annex I-11 Project carbon dioxide emissions from each of household digester

County/city	Project CO_2 emissions from coal consumption for each of household digester, tCO_2/a			
	8 m^3	10 m^3	12 m^3	15 m^3
Enshi	1.60	1.41		
Jianshi	1.63	1.55		
Badong	1.44	1.22		
Lichuan	1.67	1.53		
Xuan'en		1.52	1.47	
Xianfeng				1.61
Laifeng	1.20			
Hefeng			1.83	

Note

Project carbon dioxide emissions from each of household digester equal to EF_{cc} *multiplies project methane emissions from digester for each of household (see Annex I-9)*

Annex I-12 Total project emissions

County/city	Total project emissions, tCO_2/a				
	8 m^3	10 m^3	12 m^3	15 m^3	Total
Enshi	3,456	3,897			7,353
Jianshi	987	7,070			8,057
Badong	2,595	4,291			6,886
Lichuan	5,688	5,066			10,753
Xuan'en		3,180	1978		5,157
Xianfeng				8572	8,572
Laifeng	4,223				4,223
Hefeng			6160		6,160
Total	16,949	23,504	8139	8572	57,163

Note

The total project emissions equal to project emissions for each of household multiply household digester numbers (see table 11 and 23)

Annex II

Annex II-1 Investment costs for the physical part of project construction (SI)

	Elements	Size	№	PriceRMB	Total price thousand RMB
	For biogas electricity generation project				
1	Laboratory waste water analyse	30 m^2	1	600	18
2	Water selection	250 m^3	1		10
3	Hydraulic screen base		1		3
4	Hydrolytic acidification pond	250 m^3	1	120	30
5	Anaerobic digester	600 m^3	2	550	660
6	Steel plate for anaerobic digester	piece	2	30,000	60
7	Biogas liquid sedimentation tank	150 m^3	1	330	50
8	Steel plate for biogas liquid sedimentation tank	piece	1	10,000	10
9	Biogas storage cabinets	450 m^3	1	330	150
10	Laboratory for purification of biogas	30 m^2	1	200	60
11	Housing for biogas electricity generation	50 m^2	1	480	24
12	House for power distribution	25 m^2	1	400	10
13	Pipeline construction	1500 m			50
14	Electrical engineering	150 m			30
I	Total				1,165
	For organic fertilizer project				
15	Fertilizer production regulating pond	200 m^3	10	225	450
16	Steel plate for fertilizer production regulating pond		10	10,000	100
17	Fertilizer production factory	1500 m^2	1	150	225
18	Biogas residue drying	1000 m^2	1	150	100
19	Fertilizer composting house	300 m^2	1	300	90
II	Total				965
	For office				
20	Housing management	60 m^2	1	350	21
21	Boiler room	50 m^2	1	400	20
22	Road construction	1200 m			18
23	“Green”	2600 m			10
24	Wall construction	450 m			50
III	Total				119
	Total costs(I+II+III)				2,195

Source: MOA, 2006

Annex II-2 Investment costs for project equipment (SI)

	Elements	№	Price, thousand RMB	Total price, thousand RMB
	For biogas electricity generation project			
1	Steel grille	2	1	2
2	Steel grille	2	5	1
3	Upgrade sewage pump	10	5	54
4	Temperature control system for anaerobic digester	2	30	60
5	Electrical equipment	1	50	50
6	Biogas electricity generation	1	60	60
7	Laboratory equipment	1	30	30
8	Desulphurization	2	15	30
9	Moisture separator	1	6	6
10	Condensate traps	10	0.35	4
11	Hydraulic screen	2	40	80
12	Dry water blocking device	2	1	2
13	Biogas combustion equipment	25	2	38
14	Separator	2	130	260
15	Water device	2	12	24
16	Overflow tank	2	5	10
17	Gas flow meter	1	5	5
18	Anaerobic digester insulation layer	2	40	80
19	Flexible three-dimensional materials	200m^3	30	30
20	Fire-fighting equipment	5	10	5
21	Pipeline, valve and fitting			45
22	Construction			88
I	Total			962
	For organic fertilizer project			
23	Organic fertilizer stir device	2	45	90
24	Organic fertilizer granulator	1	25	25
25	Drying tank equipment	1	10	10
26	Boiler	1	35	35
27	Biogas sprinkler system	100	1	100
28	Biogas vehicles	2	35	70
29	Construction			33
II	Total			363
	Total (I+II)			1,328

Source: MOA, 2006

Annex II-3 Sensitivity analysis

	Reference	Thermal energy utilization	Electricity price	Thermal energy utilization	Biomass bonus	Biomass bonus
SI /SII		0/0	+10%/-10%	50%/50%	/0	/+10%
SI	-259,277	-272,368	-243,902	-246,185		
SII	14,091	999	34,691	27,182	-355,471	51,046
R for SI	-0.12	-0.13	-0.11	-0.11		
R for SII	0.073	0.068	0.056	0.077	-0.055	0.086

Note:
R: Return of rate

Annex II-4 Sensitivity analysis

	Reference	Amortization costs	Costs of repair	Biogas production	Electricity efficiency	Investment costs
SI & SII		-,+10%	+,-10%	-,+10%	-,+10%	+/-10%
SI	1.441	1.400	1.485	1.597	1.597	1.534
		1.483	1.397	1.314	1.314	1.349
SII	0.579	0.565	0.597	0.640	0.640	0.618
		0.593	0.562	0.530	0.530	0.541

Annex II-5 Break-even analysis for SII, RMB

Fix costs①	453,594	453,594	453,594	453,594	453,594	453,594	453,594
Variable①	856,386	453,594	534,152	614,710	695,269	775,827	856,386
Fix②	369,771	369,771	369,771	369,771	369,771	369,771	369,771
Variable②	772,564	369,771	450,330	530,888	611,447	692,005	772,564
Revenue	870,477	0	174,095	348,191	522,286	696,381	870,477

Notes:
① *For reference scenario*
② *The amortization costs have changed. The reason is the lifetime of CHPP is doubled. Thus, the lifetime is from 2.67 year to 5.34 years.*

Annex II-6 The “Worst”, “normal” and “best” cases analysis concerning electricity production for SI,RMB/a

Types of costs	“Worst”	“Normal”	“Best”
Amortization costs	0.506	0.414	0.338
Interest charges	0.348	0.285	0.233
Costs of insurance	0.049	0.040	0.033
Cost of payment of salaries	0.075	0.068	0.061
Fix costs	0.902	0.738	0.604
Costs of repair	0.537	0.439	0.359
Costs of process energy	0.036	0.036	0.036
Other costs	0.195	0.160	0.131
Variable costs	0.844	0.703	0.588
Revenue from electricity	0.468	0.520	0.572
Revenue from thermal energy	0	0.044	0.053

Annex II-7 The “Worst”, “normal” and “best” case analysis concerning electricity production for SII,RMB/a

Types of costs	“Worst”	“Normal”	“Best”
Amortization costs	0.199	0.132	0.131
Interest charges	0.162	0.132	0.108
Costs of insurance	0.019	0.016	0.013
Cost of payment of salaries	0.023	0.020	0.018
Fix costs	0.380	0.281	0.255
Costs of repair	0.212	0.173	0.142
Costs of process energy	0.036	0.036	0.036
Other costs	0.077	0.063	0.052
Variable costs	0.347	0.293	0.248
Revenue from electricity	0.297	0.580	0.638
Revenue from thermal energy	0	0.009	0.011

Annex II-8 Baseline emissions for SI and II

Baseline emissions:

$$BE_y = BE_{CH_4,y} + BE_{N_2O,y} + BE_{elec/heat,y}$$

A) Baseline methane emissions

$$BE_{CH_4,y} = GWP_{CH_4} * D_{CH_4} * \sum_{j,LT} MFC_j * B_{o,LT} * N_{LT} * VS_{LT,y} * MS\%_{BL,j}$$

Parameter	Value		Unit	Source
	SI	SII		
GWP_{CH4}	21	21	-	AM0010
D_{CH4}	0.00067	0.00067	t/m^3	AM0010
MCF_j	0.70	0.70		2006 IPCC guideline, volume 4, chapter 10
$B_{o,LT}$	0.13	0.13	m^3 CH_4 /kg-dm	2006 IPCC guideline, volume 4, chapter 10
N_{LT}	2000	2,000	№ of heads	At the project site
$VS_{LT,y}$	3.2	3.20	kg-dm/day	2006 IPCC guideline, volume 4, chapter 10
$MS\%_{BL,j}$	100	100	%	
$BE_{CH4,y}$	**2,972**	**2,972**	**tCO2e**	

B) Nitrous oxide emissions

$$BE_{N_2O,y} = GWP_{N_2O} * CF_{N_2O-N,N} * \frac{1}{1000} * \left(E_{N_2O,D,y} + E_{N_2O,ID,y}\right)$$

Parameter	Value		Unit	Source
	SI	SII		
GWP_{N2O}	310	310	-	AM0010
$CF_{N2O\text{-}N,N}$	44/28	44/28	-	AM0010
$EF_{N2O,D,y}$	1,372	1,372	kg N_2O-N/kg N	Default value for EF3, table 10.21
$EF_{N2O,ID,y}$	274.48	274.48		2006 IPCC Guidelines, volume 4, chapter 10
$BE_{N2O,y}$	**802**	**802**	**tCO2e**	

Baseline emissions	**3,774**	**3,774**	**tCO2e**

Annex II-9 Project emissions for SI and II

Project emissions $PE_y = PE_{AD,y} + PE_{Aer,y} + PE_{N_2O,y} + PE_{PL,y} + PE_{flared,y} + PE_{elec/heat,y}$

A) Methane leakage $PE_{AD,y} = GWP_{CH_4} * D_{CH_4} * LF_{AD} * F_{AD} * \sum_{LT} \left(B_{o,LT} * N_{LT} * VS_{LT,y}\right)$

Parameter	Value		Unit	Source
	SI	SII		
LF_{AD}	0.09	0.09	-	ACM0010
F_{AD}	100	100	%	
$PE_{AD,y}$	**77**	**385**	**tCO2e**	

B) Methane emissions $PE_{Aer,y} = GWP_{CH_4} * D_{CH_4} * F_{Aer} * \left[\prod_{n=1}^{N}\left(1-R_{VS,n}\right)\right] * \sum_{jLT}(B_{o,LT} * N_{LT} * VS_{LT,y} * MS\%_j) * (0.001 + MCF_{sl})$

Parameter	Value		Unit	Source
	SI	SII		
Faer	0.001	0.001		
1-Rvs,n	20	20	%	2006 IPCC guideline, volume 4, chapter 10
MFC_{sl}	0.0047	0.0047	ton	calculated
$PE_{Aer,y}$	**0.97**	**4.87**	**tCO2e**	

C) Nitrous oxide emissions $PE_{N_2O,y} = GWP_{N_2O} * CF_{N_2O-N,N} * 0.001 * EF_{N_2O,y} * NEX_{LT,y} * N_{LT}$

Parameter	Value		Unit	Source
	SI	SII		
$EF_{N2O,D,y}$	137.24	686.2	kg	Default value for EF3,
$EF_{N2O,ID,y}$	54.896	274.48	kg	2006 IPCC Guidelines, volume 4, chapter 10
$PE_{Aer,N2O,y}$	**94**	**468**	**tCO2e**	

Project emissions	**172**	**858**	**tCO2e**

Annex II-10 Leakage emissions for SI and II

Leakage emissions

A) Baseline

a) Methane

$$LE_{B,CH_4} = GWP_{CH_4} * D_{CH_4} * MCF_d * \left[\prod_{n=1}^{N}(1 - R_{VS,n})\right] * \sum_{j,LT}(B_{o,LT} * N_{LT} * VS_{LT,y} * MS\%_j)$$

Parameter	Value		Unit	Source
	SI	SII		
MCFd	1	1		2006 IPCC guideline, volume 4, chapter 10
Rvs,n	25	25	%	Annex 1, ACM0010
LE$_{B,CH4}$	**214**	**1068**	**tCO2e**	

b) Nitrous oxide

$$LE_{B,N_2O} = GWP_{N_2O} * CF_{N_2O-N,N} * 1/1000 * \left(LE_{N_2O,land} + LE_{N_2O,runoff} + LE_{N_2O,vol}\right)$$

Parameter	Value		Unit	Source
	SI	SII		
$EF_{N2O,land}$	110	549	kg	2006 IPCC guideline, volume 4, chapter 10
$EF_{N2O,run\ off}$	0	0	kg	2006 IPCC guideline, volume 4, chapter 10
$EF_{N2O,vol}$	22	110	kg	calculated
RN,n	40	40	%	Annex 1, ACM0010
LE$_{B,N2O}$	**64**	**321**	**tCO2e**	

B) Project

a) Methane emissions

$$LE_{P,CH_4} = GWP_{CH_4} * D_{CH_4} * MCF_d * \left[\prod_{n=1}^{N}(1-R_{VS,n})\right] * \sum_{j,LT}(B_{o,LT} * N_{LT} * VS_{LT,y} * MS\%_j)$$

Parameter	Value		Unit	Source
	SI	SII		
1-Rvs,n	16	16	%	Annex 1, ACM0010
LE$_{P,CH4}$	**137**	**684**	**tCO2e**	

b. Nitrous oxide emissions

$$LE_{P,N_2O} = GWP_{N_2O} * CF_{N_2O-N,N} * 1/1000 * \left(LE_{N_2O,land} + LE_{N_2O,runoff} + LE_{N_2O,vol}\right)$$

Parameter	Value		Unit	Source
	SI	SII		
$EF_{N2O,land}$	82	412	kg	2006 IPCC guideline, volume 4, chapter 10
$EF_{N2O,run\ off}$	0	0	kg	2006 IPCC guideline, volume 4, chapter 10
$EF_{N2O,vol}$	16	82	kg	calculated
RN,n	40	40	%	Annex 1, ACM0010
LE$_{P,N2O}$	**48**	**241**	**tCO2e**	

Leakage emissions	**-93**	**-465**	**tCO2e**

Annex III

Annex III-1 Project construction costs

	Elements	Size	№	Price	Total price
		m^3/m^2		RMB/ m^3/m^2	thousand RMB
1	Grid sump	1,000	1	400	400
2	Preparation room	500	1	500	250
3	Chicken manure slot	600	1	400	24
4	Homogenate pool	300	2	400	120
5	Feed adjustment tank	400	1	400	160
6	Sand washing tank	40	1	800	32
7	Feed pump upgrade	28	1	800	22
8	Biogas liquid storage tank	25,000	1	150	3,750
9	Solid liquid separation room	100	1	500	50
10	Solid fertilizer yard	200	1	200	40
11	Biogas residue storage tank	100	1	300	30
12	Operation room	200	1	500	100
13	Purification room	40	1	800	32
14	Management office	400	1	800	320
15	Generation room	120	1	800	96
16	Pipe inspection wells	12	1	3,000	36
17	Valve shaft	18	1	3,500	63
18	Three wells	2	1	5,000	10
I	Total costs				5,535

Annex III-2 Project investment costs for equipment

	Equipment	Capacity, kW	№	Price, thousandRMB/ kW	Total price, thousandRMB
19	High-rate anaerobic digester		4	2,300	9,200
20	Dry air storage cabinets		1	2,000	2,000
21	Chicken manure enhance screw pump	18.5	2	80	160
22	Anaerobic feed screw	11.5	3	30	90
23	Homogenate pool screw pump for sand mention	5.5	2	24	48
24	Feed screw sand pond raised	5.5	1	24	24
25	Homogenate pool matching mixer	11	2	69	138
26	Feed pool mixer	11	1	72	72
27	Odour absorption system	15	1	150	150
28	Anaerobic tank mixer	18.5	8	110	880
29	Machine grid	1.1	1	60	60
30	Submersible sewage pump	4	3	5	15
31	Solid-liquid separator	5.5	6	95	570
32	Spiral decanter	5.5	4	90	360
33	Sand- water separator		2	50	100
34	Screw conveyor	1.1	2	35	70
35	Anaerobic tank operating platform		1	180	180
36	Bio-desulphurization tower	3.0	4	210	840
37	Dry desulphurization tower		4	50	200
38	Gas-water separator		4	15	60
39	Condensate water trap		5	4	20
40	Dry-type flame arresters		2	4	8
41	Biogas flow meter	0.75	1	28	28

42	Reactor detector	0.55	4	110	440
43	Process piping		1	750	750
44	Valve fittings	10	1	378	378
45	PLC control system		1	800	800
46	Electrical equipment, monitoring system		1	650	650
47	CHPP		2	7,800	15,600
48	Laboratory instruments	15	1	120	120
49	Power generation transmission and distribution system		1	1,700	1,700
50	Heat utilization system		1	800	800
II	Total				36,511

Annex III-3 Total costs

	Other costs		Total price, thousandRMB
51	Direct investment	I+I	42,046
52	Survey and design	4% from direct investment	1,682
53	Report preparation		50
54	EIA report preparation		10
55	Bidding		198
56	Review drawing	5.0% from survey and design costs	84
57	Construction	1.07% from direct investment	450
58	Built drawing preparation	8.0% from survey and design costs	135
59	Management		184
60	Engineering insurance	0.22% from direct investment	93
61	Other unforeseeable costs	8% from direct investment	3,364
III	Total		48,294

Annex III-4 Sensitivity analysis for SI and II

	Reference	Biomass bonus	Biogas production	Electricity efficiency	Thermal energy	Investment costs	Amortization costs
SI /SII		0,+10%	-,+10%	-,+10%	0,+50%	+,-10%	-,+10%
SI	0.085	-0.087	0.041	0.044	0.050	0.056	0.064
		0.192	0.130	0.126	0.103	0.130	0.106
SII	0.131	-0.110	0.068	0.074	0.074	0.083	0.101
		0.155	0.194	0.189	0.160	0.219	0.161

Annex III-5 Break-even analysis for SI,RMB/a

Fix costs①	7,322,839	7,322,839	7,322,839	7,322,839	7,322,839	7,322,839
Variable①	0	458,043	316,087	1,374,130	1,832,173	2,290,216
Total	7,322,839	7,780,883	8,238,926	8,696,970	9,155,013	9,613,056
Revenue	0	2,205,202	4,410,405	6,615,608	8,820,811	11,026,014

Annex III-5 Break-even analysis for SII,RMB/a

Fix costs①	6,060,980	6,060,980	6,060,980	6,060,980	6,060,980	6,060,980
Variable①	0	363,346	726,694	1,090,040	1,453,387	1,816,735
Total	6,060,980	6,424,327	6,787,674	7,151,021	7,514,368	7,877,715
Revenue	0	1,784,063	3,568,127	5,352,190	7,136,253	8,920,317

Annex III-6 “Worst”, “normal” and “best” cases analysis concerning electricity production for SI,RMB/a

Types of costs	“Worst”	“Normal”	“Best”
Amortization costs	0.346	0.311	0.283
Interest charges	0.129	0.106	0.086
Costs of insurance	0.018	0.015	0.012
Cost of payment of salaries	0.041	0.037	0.034
Fix costs	0.534	0.469	0.415
Costs of repair	0.054	0.044	0.036
Costs of process energy	0.037	0.037	0.037
Other costs	0.072	0.059	0.048
Variable costs	0.163	0.140	0.122
Revenue from electricity	0.381	0.690	0.715
Revenue from thermal energy	0	0.059	0.059

Annex III-6 “Worst”, “normal” and “best” cases analysis concerning electricity production for SII,RMB/a

Types of costs	“Worst”	“Normal”	“Best”
Amortization costs	0.335	0.301	0.274
Interest charges	0.131	0.107	0.087
Costs of insurance	0.018	0.015	0.012
Cost of payment of salaries	0.033	0.030	0.027
Fix costs	0.517	0.453	0.401
Costs of repair	0.055	0.045	0.037
Costs of process energy	0.037	0.037	0.037
Other costs	0.073	0.060	0.049
Variable costs	0.165	0.142	0.123
Revenue from electricity	0.381	0.682	0.707
Revenue from thermal energy	0	0.051	0.051

Annex III-7 Baseline emissions

Baseline emissions: $BE_y = BE_{CH_4,y} + BE_{N_2O,y} + BE_{elec/heat,y}$

A) Baseline methane emissions $BE_{CH_4,y} = GWP_{CH_4} * D_{CH_4} * \sum_{j,LT} MFC_j * B_{o,LT} * N_{LT} * VS_{LT,y} * MS\%_{BL,j}$

Parameter	Value		Unit	Source
	Pheasants	Layer chicken		
GWP_{CH4}	21	21	-	AM0010
D_{CH4}	0.00067	0.00067	t/m^3	AM0010
MCF_j	0.66	0.66		2006 IPCC guideline, volume 4, chapter 10
$B_{o,LT}$	0.24	0.39	m^3 CH_4 /kg-dm	2006 IPCC guideline, volume 4, chapter 10
N_{LT}	500,000	2,500,000	№ of heads	At the project site
$VS_{LT,y}$	0.02	0.03	kg-dm/day	2006 IPCC guideline, volume 4, chapter 10
$MS\%_{BL,j}$	100	100	%	
$BE_{CH4,y}$	8,110	87,860	tCO2e	
Total	**95,970**		**tCO2e**	

B) Nitrous oxide emissions $BE_{N_2O,y} = GWP_{N_2O} * CF_{N_2O-N,N} * \frac{1}{1000} * \left(E_{N_2O,D,y} + E_{N_2O,ID,y}\right)$

Parameter	Value		Unit	Source
	Pheasants	Layer chicken		
GWP_{N2O}	310	310	-	AM0010
$CF_{N2O\text{-}N,N}$	44/28	44/28	-	AM0010
$EF_{N2O,D,y}$	0	0	kg N_2O-N/kg N	Default value for EF3, table 10.21
$EF_{N2O,ID,y}$	179.58	7270.8		2006 IPCC Guidelines, volume 4, chapter 10
$BE_{N2O,y}$	87	3542	tCO2e	
Total	**3629**		**tCO2e**	

$$BE_{elec/heat,y} = EG_{BI,y} * CEF_{BI,elec,y} + EG_{d,y} * CEF_{grid} + HG_{BI,y} * CEF_{BI,th,y}$$

C) Carbon dioxide emissions $BE_{elec/heat,y} = EG_{BI,y} * CEF_{BI,elec,y} + EG_{d,y} * CEF_{grid} + HG_{BI,y} * CEF_{BI,th,y}$

Parameter	Value	Unit	Source
$EG_{BI,y}$	0.182	GWh	At the project site
$CEF_{BI,elec,y}$	0.9826	tCO2/MWh	China North power grid
$EG_{d,y}$	16,876	MWh	At the project site
CEF_{grid}	0.9826	tCO2/MWh	China North power grid
Total	**16,761**		**tCO2e**

Baseline emissions	**116,361**	**tCO2e**

Annex III-8 Project emissions

Project emissions $PE_y = PE_{AD,y} + PE_{Aer,y} + PE_{N_2O,y} + PE_{PL,y} + PE_{flared,y} + PE_{elec/heat,y}$

a) Methane leakage $PE_{AD,y} = GWP_{CH_4} * D_{CH_4} * LF_{AD} * F_{AD} * \sum_{LT} \left(B_{o,LT} * N_{LT} * VS_{LT,y}\right)$

Parameter	Value		Unit	Source
	Pheasants	Layer chicken		
LF_{AD}	0.15	0.15	-	ACM0010
F_{AD}	100	100	%	
$PE_{AD,y}$	776	8,412	tCO2e	
Total	**9,189**		**tCO2e**	

b) Methane emissions $PE_{Aer,y} = GWP_{CH_4} * D_{CH_4} * F_{Aer} * \left[\prod_{n=1}^{N}\left(1 - R_{VS,n}\right)\right] * \sum_{jLT}(B_{o,LT} * N_{LT} * VS_{LT,y} * MS\%_j) * (0.001 + MCF_{sl})$

Parameter	Value		Unit	Source
	Pheasants	Layer chicken		
Faer	0.3	0.3		
1-Rvs,n	30	30	%	2006 IPCC guideline, volume 4, chapter 10
MFC_{sl}	0.1	0.1	ton	calculated
$PE_{Aer,y}$	1.11	12.02	tCO2e	calculated
Total	13.13		**tCO2e**	

c) Nitrous oxide emissions $PE_{N_2O,y} = GWP_{N_2O} * CF_{N_2O-N,N} * 0.001 * EF_{N_2O,y} * NEX_{LT,y} * N_{LT}$

Parameter	Value		Unit	Source
	Pheasants	Layer chicken		
$EF_{N2O,D,y}$	66	2,656	kg	Default value for EF3,
$EF_{N2O,ID,y}$	27	1,063	kg	2006 IPCC Guidelines, volume 4
$PE_{Aer,N2O,y}$	**3,812**		tCO2e	

Project emission	**13,014**		**tCO2e**