EC-ASEAN ENERGY FACILITY

Feasibility Study for the Generation of Renewable Energy from Organic Waste and Biomass on Phu Quoc Island, S.R.Vietnam

Version 1.0

June 2006

Co-funded by the European Commission within the framework of the EC-ASEAN Energy Facility Programme (EAEF)

This feasibility study was produced by the following consortium of six institutions from Europe and Vietnam, within the framework of the project:

"Development of practice oriented guidelines for the preparation of feasibility studies on the production of renewable energy from organic waste and biomass by biogas plants and biomass combustion plants, with an applied example for Phu Quoc/S.R.Vietnam" (Acronym: RENEW)

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Co-funded by the European Commission within the framework of the EC-ASEAN Energy Facility Programme (EAEF)

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List of Abbreviations

€	European currency (Euro)
APEC	Asia Pacific Energy Research Centre
ASEAN	Association of South East Asian Nations
Bfai	Bundesagentur für Außenwirtschaft
DIHK	Deutsche Industrie- und Handelskammer
BOD	Biological Oxygen Demand
BOT	Build Operate Transfer Project
CBA	Cost-Benefit-Analysis
CDM	Clean Development Mechanism
CERs	Emissions Reductions Certificates
CH_4	Methane
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
DIA	Department of International Cooperation, Vietnam
DNA	Designated National Authority
DOC_F	Dissolved Organic Carbon
DS	Dry Substance
EFB	Empty Fruit Branches
EPC	Engineering, Procurement and Construction Contractor
ESCOs	Energy Service Companies
EVN	Electricity of Vietnam
FDI	Foreign Direct Investment
FFB	Fresh Fruit Branches
GEF	Global Environment Facility
GHG	Green House Gas
GWh	giga Watt hours
HAPUA	Heads of ASEAN Power Utilities/Authorities
hrt	hydraulic retention time
HWWA	Hamburgisches Welt-Wirtschafts-Archiv

ICRA	Information for the Commercialization of Renewable Energy in ASEAN
IE	Institute of Energy (Hanoi/Vietnam)
IEA	International Energy Agency
IGES	Institute for Global Environmental Strategies
IPP	Independent Power Producer
IREDA	Indian Renewable Energy Development Agency
IRR	Internal Rate of Return
kg	kilo gram
kWh	kilo Watt hours
MCA	Multi-Criteria-Analysis
MOI	Ministry of Industry (Hanoi/Vietnam)
m_S	mass to be disposed after treatment
Mg	mega gram
MWh	mega Watt hours
Non-SSC-Project	Non-Small-Scale-CDM-Project
O&M Contractor	Operation and Maintenance Contractor
OAV	Ostasiatischer Verein e. V.
ODA	Overseas Development Assistance
oDS	organic Dry Substance
OECD	Organization for Economic Cooperation and Development
OLR	Organic Loading Rate
PC 2	Power Company 2 (Ho Chi Minh City/Vietnam)
PIM	Project Information Memorandum
PPP	Public Private Partnership
R&D	Research and Development
RE	Renewable Energy
REAP	Renewable Energy Action Plan
RES	Renewable Energy Systems
SMEs	Small and Medium Sized Enterprises
SSC-Project	Small-Scale-CDM Project
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VND	National currency of Socialist Republic of Vietnam (Vietnamese Dong)

I Executive Summary

Against the background of global climate change and increasing prices of fossil fuel, the importance of producing sustainable, renewable energy increases significantly. Carbon dioxide neutral energy generation using biomass or organic waste is an alternative option that deserves attention particularly in countries like Vietnam. Due to favourable climatic conditions and the prevailing economic structure, potential input materials, i.e. organic substrates from farming, forestry and waste, are very abundant.

An example for the suitable application of a renewable energy facility is Phu Quoc Island. It is the biggest Island of Vietnam, situated 30 km off the mainland. It belongs to Kien Giang Province, with a total area of 568 km² and more than 85,000 inhabitants. The provincial government plans to develop Phu Quoc Island as one of the country's leading tourist destinations. Also, it is the political aim to "keep the island green" by promoting sustainable development and eco-tourism. The increasing number of tourists and anticipated population growth will lead to considerable infrastructure developments. Therefore, appropriate measures will be required to avoid adverse impacts on the environment.

Currently, electricity is generated by diesel-based decentralised power generation facilities with a total capacity of 10 MW. The supply is not sufficient to meet the current demand. In addition, the island's north will be linked to the main grid network within the next couple of years, leading to a further increase of demand. Due to diesel dependency, electricity tariffs for the end consumer are relatively high and will continue to increase.

Prevailing framework conditions of Phu Quoc Island are very favourable for the application of renewable energy processes using biogas or biomass combustion technologies. It would lead to an improved and cheaper energy supply and thus would represent the basis for further economic growth and improved standard of living. As side benefit, prevailing problems related to the current waste handling practices would be addressed, leading to considerable improvements of the local environmental conditions. The fertiliser produced as by-product of a biogas process could be applied for the extensive agricultural activity on the island und substitute imported mineral fertiliser. As a consequence, this integrated approach is in line with the development goals set by the local and regional governments and thus will receive support from relevant project stakeholders.

Overall objectives of the RENEW-Project

The objectives are to promote environmental protection at global and local level by supporting the implementation of renewable energy solutions. The installation of a renewable energy facility on Phu Quoc can serve as demonstration plant for an appropriate solution for ASEAN countries and European know-how and technology. Furthermore, RENEW aims to contribute to the cooperation between countries of the European Union and ASEAN member countries by the transfer and exchange of knowledge and know-how in the field of renewable energy. Project objective is also to promote the ASEAN Plan of Action for Energy cooperation 1999-2004 and to support of the export of European products and services of the renewable energy sector into the ASEAN.

For that reason, a feasibility study has been produced assessing suitable options regarding location and technology for the implementation of renewable energy facilities on Phu Quoc Island.

II Summary of Important Facts and Recommendations

Main Results of the Feasibility Study

According to the master plan for the development of Phu Quoc Island, there are two locations for new landfills (approved by the decision No. 178/2004/QD-TTg of the Prime Minister Phan Van Khai). Both, Option A: near Cua Can and Option B: near Ham Ninh, have been found suitable for the implementation of biogas and biomass combustion plants on Phu Quoc Island. Due to infrastructural considerations the location near Ham Ninh has some advantages leading to a recommendation as favourable option.

The study revealed that the implementation and operation of both technical options (Option 1: biogas plant and Option 2: biomass combustion plant) are possible and will have several advantages against the current situation. Utilising biomass and organic waste from agriculture, households, hotels and other businesses, they also represent efficient waste treatment systems. Environmental problems like ground water pollution, smell or diseases arising from uncontrolled disposal of untreated waste can be eliminated. Thus, both remaining technology options are cost-efficient and environmentally sound options that are suitable for decentralised applications.

It will be technically and economically feasible to implement a 500 kW_{el} dry fermentation biogas plant (e.g. BEKON process) with an input of 15,000 Mg household waste per year. The household waste from Phu Quoc will be treated by anaerobic digestion (biogas process) so that environmental damages by uncontrolled waste disposal of untreated waste -the current practice- will be reduced. The solid output of the process will be further treated. A sieved and composted fraction can be utilised as fertiliser. The remaining material is sufficiently stabilised for disposal on a landfill site. The total capital investment is required to be approx. 3.3 million €.

It will also be feasible to implement a combustion process. A combination of a solar drying process and a combustion plant with energy recovery by the innovative Pebble-Heater technology matches the requirements of Phu Quoc. Due to the relatively simple Pebble-Heater technology, the investment is lower than for other technical combustion solutions. The electricity output is estimated to be about 1.2 MW_{el} for an overall input of 16,000 Mg waste per year.

Recommendation of the Consortium

A dry fermentation technology was found potentially suitable for the given framework conditions and had been assessed in the feasibility study. Considering all results, the Consortium finally recommends the implementation of a biogas plant on Phu Quoc Island. A dry fermentation biogas plant, e.g. the BEKON process, will have a number of benefits:

- The modular BEKON dry fermentation process is more flexible than a combustion plant. It can be adapted easily to increasing waste quantities and changing waste composition to match future developments on Phu Quoc.
- The biogas plant is operated as batch process and therefore can deal with short-term changing quantities of input material (e.g. small waste quantities in low-season for tourism).
- The biogas plant will require less capital investment than the combustion plant (5.7 million €).
- The type of waste which will be used as input material is characterized by a high water content and therefore is more suitable for the utilization in a biogas plant.
- The biogas process supports the recycling of material. A major fraction of the solid output is digested organic substrate which can be utilized as fertilizer in local agriculture. The import of mineral fertilizer can be reduced and the soil quality can be improved.

1 Introduction

1.1 Scope of the Feasibility Study

The feasibility study aims to develop and support relationships between ASEAN countries and the countries of the EU. Specifically to support the transfer of expert knowledge, to increase economic exchange and to export European products into the ASEAN market in the field of renewable energies. The preparation of feasibility studies requires specialists know-how, especially in ASEAN countries which is not readily available for most European small and medium sized companies, for example suppliers and manufacturers of renewable energy equipment, because of barriers in the legal, cultural and technical system. The feasibility study for Phu Quoc, Vietnam, will serve as an example for how this type of study is done.

Feasibility studies are a pre-requisite for the positioning of European small and medium sized enterprises on the ASEAN market, thus these companies need support and assistance in this field. Therefore this exemplary feasibility study will describe stepwise how to conduct a Feasibility Study in ASEAN countries. The island Phu Quoc in Vietnam is chosen to be the area for the Feasibility study.

The feasibility study aims to evaluate the possible success of a renewable energy project on Phu Quoc. The development and expansion of the renewable energy on the island will help to improve and secure the energy supply and support sustainable development, and also promote the ASEAN plan of Action for Energy cooperation (1994-2004). Positive outcome is in addition the reduction of pollution on a local level and the environmental protection on a global level.

Based on collected framework data and information, and their subsequent assessment, three different options (two technologies and their combination) for generation of energy from renewable sources are discussed. Different possible locations for the plant will be evaluated as well. The feasibility study will outline those options by describing their technical concept (i.e. substrate supply, process and facilities, construction), energy utilisation, distribution aspects and the recycling (like the disposal or reuse of products or organic waste from the plant). Furthermore economic issues like investment, operation, maintenance and energy production costs, revenue, economic viability and financing options are researched and evaluated. In addition environmental aspects as well as socio-economic, social and cultural impacts are considered and finally legislative constrains are described.

On the basis of this the project findings will be summarised and a multi criteria analysis will be applied including a sensitivity analysis. According to the results of these analyses, a favourable option will be presented and a recommendation of further activities for the project development and it's implementation will be given.

1.2 Need for the Feasibility Study

Currently the energy supply in Phu Quoc can not meet the demand which increases annually by about 10-14%, due to growing population and wealth. More than 40% of the population live without energy[1]. According to the Asia Alternative Energy Program of the World Bank[2], over 3 million rural households in Vietnam will remain without electricity in 2010, despite the grid-based rural electrification program of the government. In addition there is no adequate waste management on the island. There is a general need for sustainable development of both industries. With the help of a feasibility study a scientifically and technically sound pre-requisite for further planning and implementation of renewable energy plants that utilise organic waste can be ensured.

The overall potential of renewable energy applications in Vietnam is high, particularly for decentralised applications. Approximately 80% of its population live in rural areas where organic energy sources like biomass are very abundant. Thus, there is an overall good potential for the application of renewable energy from biomass in Vietnam; the availability of substrate and users of energy as well as by-products such as compost, together with the absence of a centralised electricity supply make decentralised supply particularly attractive. Biogas and biomass combustion processes do not contribute to the global warming effect (unlike fossil fuels) due to emission of neutral CO_2 only. By feeding organic waste into the biogas process and preventing uncontrolled anaerobic digestion in landfills and dumps, the release of methane into the atmosphere is reduced. Both processes have a positive effect on the local environment as well. It will reduce the need for conventional diesel generators, which are responsible for air and noise pollution and uncontrolled waste disposal including its negative effects like water pollution, soil pollution and smell will be reduced by utilising organic waste in biogas or biomass combustion plants.

According to FAO[3] the typical constraints to optimal use of renewable energy in ASEAN countries are legal and institutional barriers as well as lack of information and technology transfer. Systematic data are still inadequate for biomass planning and for developing energy policies on supply and demand. Thus there is a demand for demonstration plants for renewable energy generation, which will show technical and economic feasibility as well as resulting benefits.

Decision makers on Phu Quoc have already shown much interest in renewable energy generation and innovative techniques. On a concrete level, the feasibility study for Phu Quoc regarding renewable energy generation will directly support local activities to secure energy supply. As the island is situated far from the mainland, there is no connection to the national grid. Electricity generation relies on diesel, is expensive and the increasing demand cannot be met. Moreover the Prime Minister decided to develop the island sustainable towards eco-tourism and therefore the regional authority needs to decide upon a solution and welcomes a decision basis. The Phu Quoc-case can represent an example that is transferable to other regions.

1 ASEAN Centre for Energy (2000)

2 ASTAE, (1999): Options for renewable Energy in Vietnam-A report on the June 15-16, 1999 two-day participatory workshop in Hanoi

3 FAO (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS) (1999): Bioenergy. Conference on the Multifunctional Character of Agriculture and Land, Maastricht (MFCAL, 12-17 September 1999)

1.3 Target Groups

The feasibility study aims at enhancing exchange between ASEAN and European companies interested in implementing renewable energy projects. One target group are thus small and medium sized European businesses that try to position themselves on the Asian market. Another target group are ASEAN companies that are interested in pushing the sector of renewable energies in their country. This study provides information on European products to ASEAN decision-makers. This will rise interest in European services and products (e.g. pumps for biogas plants, generators, plant concepts like the dry fermentation process, etc.). If implemented, the suggested renewable energy plant for Phu Quoc will represent the first demonstration plant in Vietnam, showing European Technology. For companies from the ASEAN region, the project offers international know-how of a unique quality. They will be supported in developing new market sectors (renewable energy options; feasibility studies).

The study is also aimed at local or regional decision makers, representatives of administration and stakeholders involved in energy supply and sustainable development on Phu Quoc. It will sever to increase the understanding and awareness of local decision makers to help make informed decisions and contribute recommendations to the planning process.

Implementing renewable energy facilities will also improve the situation of inhabitants and tourists of Phu Quoc, they are an indirect target group that will gain additional information through the study but most of all benefit from it. The island will be supplied with cost effective, renewable energy, the environment is secured, noise, air pollution and uncontrolled waste disposal is minimised which could indirectly attract more tourists to visit Phu Quoc for holidays leading to increased employment levels for Phu Quocs inhabitants.

1.4 Methodology

1.4.1 Data Inventory

The data inventory is used for the evaluation of the framework conditions. The partners with excellent local knowledge carry out the inventory. The data collection is done stepwise. The inventory can be carried out stepwise, starting with a coarse screening to more detailed data collection. For the selected options and sub-options, data with a high level of detail will be collected, which is needed for assessing the feasibility for each of these options and to compare the options among each other.

All together a broad variety of data are collected. The quality and quantity of substrates, which are available for the generation of renewable energy, are investigated, e.g. the regional distribution, characteristics like dry substance content, typical contamination, etc.. All suitable substrates that are available on the Island of Phu Quoc are included in the assessment: substrates from organic waste and waste water, substrates from agriculture or forestry, agro-industry or other industry (e.g. food processing). The whole island is screened to determine the location of potential sites. The favourable options have been identified and detailed information on substrate availability (e.g. seasonal distribution) and quality for every site is presented.

Frame conditions regarding energy aspects today and in the (near) future are investigated and possible plant locations and technical feasibility are determined. This includes data on energy demand, net capacity, network supply and the point of delivery.

Information on the environment and environmental sensitivity are collected. The possible locations for installation of energy generation plants are given under the light of environmental and natural conditions. The evaluation of the environmental impact is determined by the local environmental conditions. For the favourable sites, relevant site specific information is collected, e.g. special requirements or restrictions regarding buildings or plants, ownership and easement for site and roads; maps, historic analysis regarding possible soil contamination etc.. Furthermore, information regarding logistic requirements, e.g. possible transportation options, distances, costs, etc. need to be considered. Finally other aspects, like legal, regulatory, policy; socio-cultural, economic, socio-economic factors are collected for Phu Quoc, and if special conditions apply, for the favourable sites.

In RENEW, Life Cycle Analysis (LCA) is used as a decision making tool for alternative processes compared to conventional solutions. The basic methodology of a LCA is based on 4 steps:

1 Definition of the scope and the subject of the assessment
2 Data inventory
3 Impact assessment
4 Improvement assessment

The LCA tool has been used to evaluate the environmental aspects of the project and specifically the GEMIS software has been used to calculate the emissions for the three options to be examined proposed during the projects kick-off meeting. The environmental indicators both on local and global level for the evaluation of each proposed option have been identified and presented to all partners. During the projects workshop all methodological analysis of the life cycle assessment procedure has thoroughly been introduced to the project partners.

1.4.2 Assessment of the Feasibility

All property, technical, financial, and organizational risks of the implementation of such projects have been identified and assessed and evaluated. Quantitative classification was not able to be performed due to the qualitative nature of the data, whereas qualitative assessment has been made for each of the aforementioned risks. The need to and extent to control the risks associated with renewable energy projects have been examined. A proposed framework for categorizing risks by their nature has been introduced during the December 2006 workshop. The assessment for each of the proposed options has been presented during the workshop as well as a wider framework for assessing the risks connected with the implementation of such projects. Thorough discussion has taken place during the project's workshop concerning especially financial risks connected to such projects following the presentation of the financing tools for the implementation of renewable energy projects in developing countries.

1.4.3 Comparison of Options

The multi-criteria analysis (MCA) is a tool to determine overall preferences among alternative options and thus support the decision-making process. Complex situations or processes, such as biogas production and biomass combustion, are often connected to multiple criteria which can cause confusion when making a decision. The MCA is a structured approach based on the definition of objectives and corresponding attributes or indicators to overcome these uncertainties of the judgement. There are different techniques applicable to carry out a MCA.

However all techniques imply the choice and definition of explicit objectives and measurable criteria and the application of scores or relative importance weights.

1.4.4 Recommendations

For the decision making procedure for the practical guidelines preparation the results of LCA for selected technological solutions are utilized. Moreover the risk assessment evaluation is used to enhance and complement the LCA results for the decision making procedure. Thorough literature review is available and certain steps for the preparation (i.e. data collection and evaluation) and actual analysis are proposed. Finally a number of commercial software for life cycle assessment are considered and the reasons (i.e. extended database, specific datasets for Asian countries, biomass and biogas specific facilities included) for the selection of specific package are analysed.

2 Options for Renewable Energy Assessed

This feasibility study represents a vital prerequisite for the implementation of a new (and renewable) energy producing facility. The aims and objectives of the feasibility study had been defined by the Consortium, together with local decision-makers from Phu Quoc.

2.1 Options Regarding Location (Option A and B)

It was found that landfill sites are potentially suitable for the possible location of the renewable energy plants. The main reasons are that substrate and infrastructure for logistic and waste handling are readily available.

Two new landfills are planned to be situated near the villages Cua Can and Ham Ninh (see Figure 2-1). This is according to the master plan for the development of Phu Quoc Island, which has been approved by the decision No. 178/2004/QD-TTg of the Prime Minister Phan Van Khai.

Considering this master plan, two different locations for the future renewable energy plant have been assessed in this feasibility study:

Option A: Cua Can, Phu Quoc

Option B: Ham Ninh, Phu Quoc

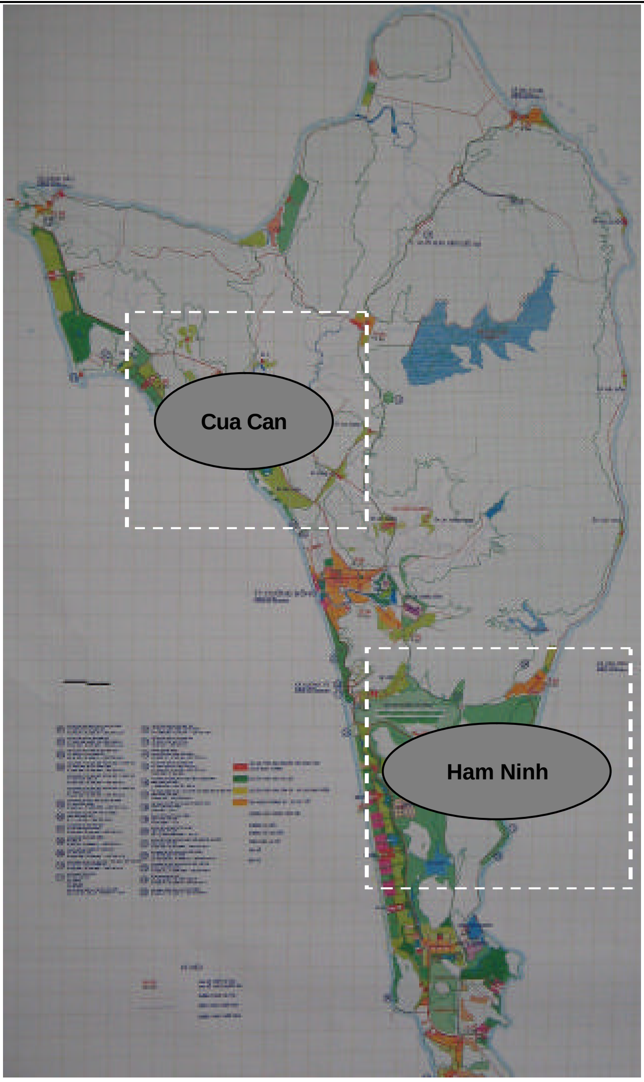


Fig. 2-1a: Planned locations for new landfill sites near Cua Can and Ham Ninh on Phu Quoc Island, S.R. Vietnam

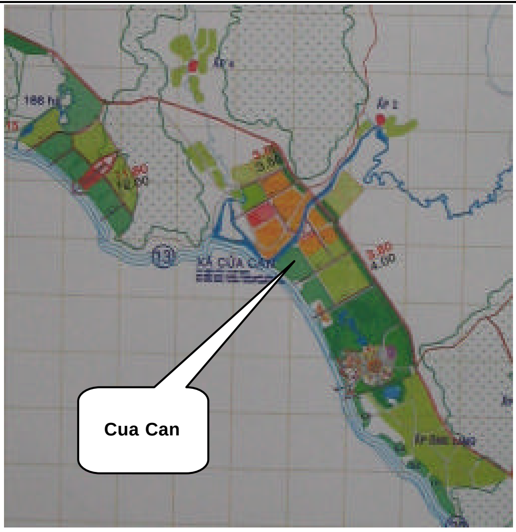


Fig. 2-1b: Masterplan for Cua Can and northwest Phu Quoc

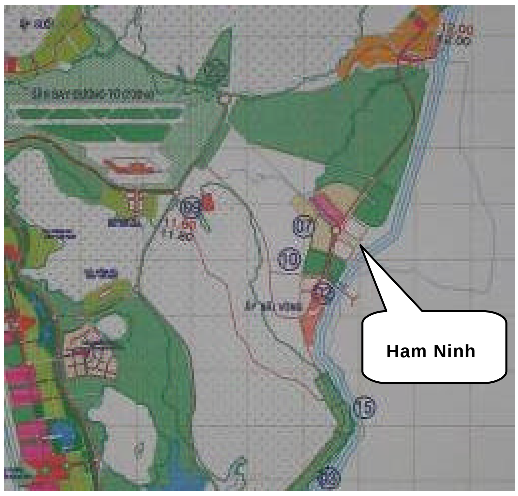


Fig. 2-1c: Masterplan for Ham Ninh and Phu Quoc's centre

Figure 2-1: Map of the masterplan for the development of Phu Quoc, showing planned locations for new landfill sites on the island, near the villages Cua Can and Ham Ninh

2.2 Options Regarding Technology (Option 1, 2, 3)

In addition to locality three options for technology were defined. These options differ with regard to the technology used for renewable energy production from biomass and organic waste:

Option 1: Biogas plant (dry fermentation technology)

Option 2: Biomass combustion plant (pebble heater process)

Option 3: Combined biogas and biomass combustion plant

Both processes, biogas and biomass combustion, are suitable for energy generation by utilising biomass or organic waste from households, hotels, agriculture and other businesses. This means that the processes can also be combined with an efficient waste treatment systems. This in turn can help to minimise environmental problems related to a lack of waste management.

3 Framework Conditions for Renewable Energy Generation on Phu Quoc

3.1 General Framework at Phu Quoc

3.1.1 Geography

The Phu Quoc district – in Kien Giang province – is an archipelago located in the gulf of Thailand it takes a very important place in the development of aspects of national security and economy. Phu Quoc district consists of Phu Quoc Island, An Thoi archipelago, Tho Chau archipelago and the other 36 islands. Phu Quoc island – the biggest island in Vietnam (same area size as Singapore) - lies on:

103°29' to 104°9' East longitude and 9°48'27'' to 10°26'30'' North latitude

Figure 3-1: Map of Phu Quoc island (including Mekong Delta key map)

The total area of Phu Quoc district is around 593 km² of which Phu Quoc island is around 561 km², An Thoi archipelago (at south of Phu Quoc island) takes around 5km², Tho Chau archipelago (102 km from Phu Quoc island and 200 km from Rach Gia town) has the area of 26 km².

Phu Quoc Island has the triangular shape with the base at the North and the top at the South. The longest distance in North - South direction is 49 km, the largest East – West distance in the North of island is 27 km and the smallest is 3 km in the South. The island perimeter is 150 km. The North side of island is 15 km from Cambodia inland and 46 km from Ha Tien town, in the East it is 115 km from Rach Gia town.

64.2% of the area of Phu Quoc Island has altitude = 40 m. This area is covered by mountains and forests; the slope of this area is over 40°. The altitude on Phu Quoc Island descends gradually from the North to the South of island. Altogether 99 mountains are located at the North of island. Most of these mountains have a steep slope on East side and a gentle slope on West side. The longest slope is Ham Ninh which stretches for 30 km along the eastern edge with its highest peak called Mt. Chua (605 m). The mountains at the West and South of island have the altitude less than 200 m.

3.1.2 Climate

Phu Quoc has a monsoon sub-equatorial climate. There are two seasons in the year: the rainy season and the dry season.

Phu Quoc is warm all year round with seasonal variations of less than three degrees Celsius. The annual mean temperature is around 27.8°C (data of 2002) among which the monthly average temperature in the hottest months (April and May) is around 29.5°C, and in the coldest month (January) is around 25.9°C.

Phu Quoc receives around 3,037 mm of rain per year, higher than that of Vietnam, and a long rainy period (174 day/year). The rainfall is strongest in August therefore the risk of flooding is very high, floods in this month usually prolong for 3-5 days.

The humidity varies with the two seasons. In general, the monthly humidity is 74-82% during the dry season, and increases to 86% during the rainy season. The difference between hightest and lowest humidity varies between 11-12%.

The total annual sunshine is 2,500 hours. In the dry season, the total sunshine is highest which is why it is also referred to as sunshine season. In April, the sunshine hour is highest with 9 hours/day. In the rainy season, the sunshine hour is around 5-6 hours/day.

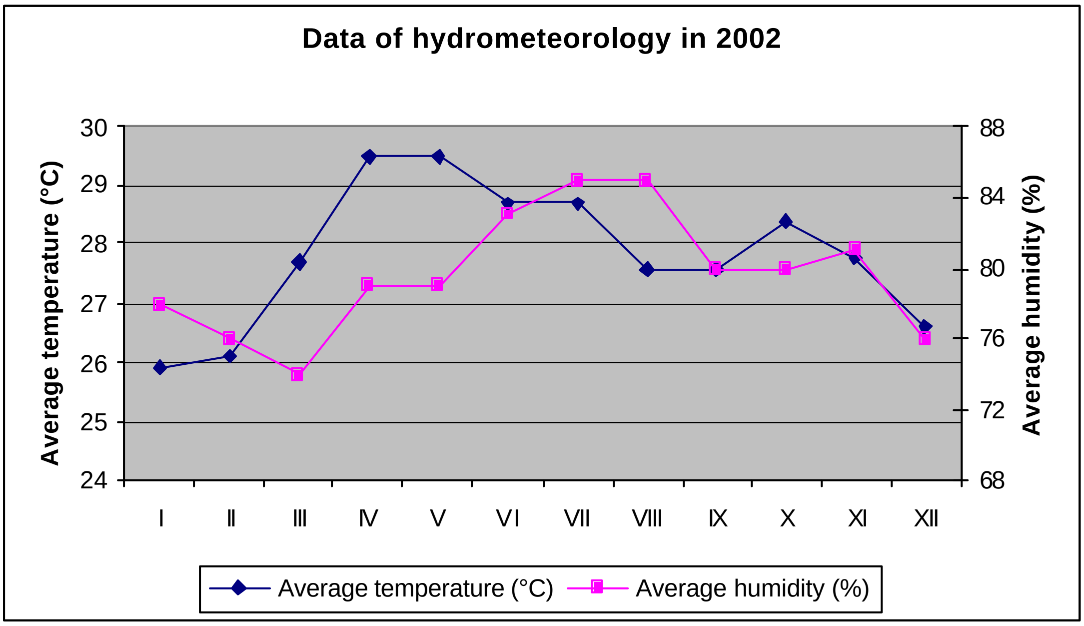


Figure 3-2: Monthly mean temperature and monthly mean humidity at Phu Quoc in 2002

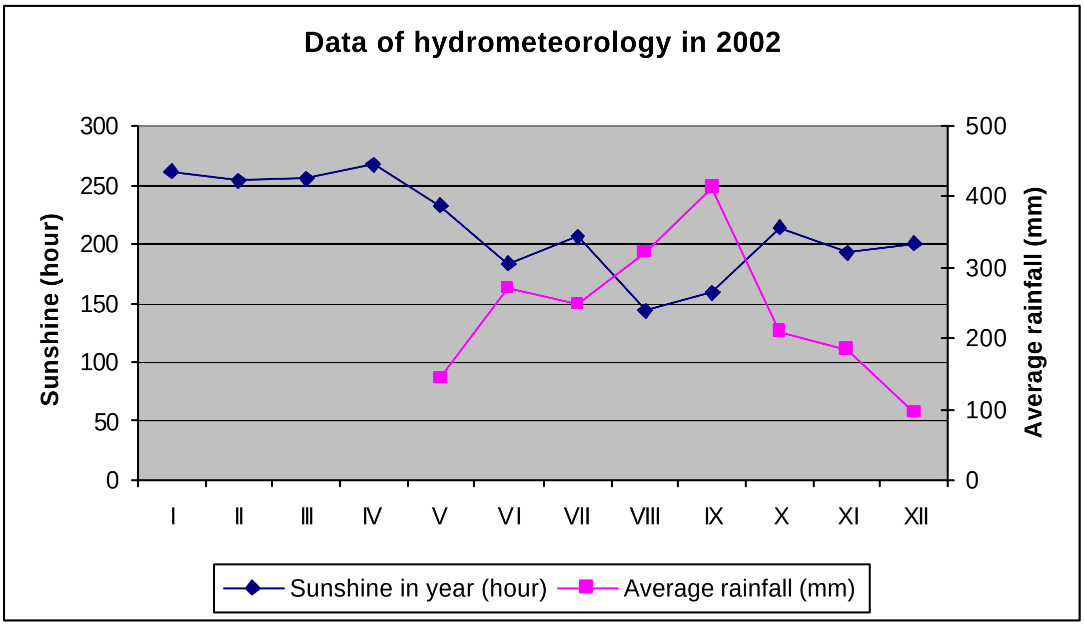


Figure 3-3: Monthly mean sunshine hour and monthly mean rainfall at Phu Quoc in 2002

3.1.3 Administrative Units

Phu Quoc has 10 administrative units including Duong Dong town, An Thoi town and 8 communes (Cua Duong, Cua Can, Bai Thom, Ganh Dau, Ham Ninh, Duong To, Hon Thom, and Tho Chau). Duong Dong town -located at the island centre- is the centre of political, economical, cultural and social activities of the island. An Thoi town at the southern tip of the island and serves as a popular fisheries port.

3.1.4 Natural Resources

3.1.4.1 Soil

There are four main soil types at Phu Quoc:

- Sandy soil covers 18.6% area of Phu Quoc including sea sand and sand dunes. These types of soil are distributed along the sea side and in the West and South-East of the island.
- Alluvial soil covers 1.98% area of Phu Quoc distributed mainly at Duong To, Ham Ninh, An Thoi and Cua Can communes.
- Grey soil covers 17.4% area of Phu Quoc including grey soil on Acidic Magma stone base at the high land and grey soil with red and yellow-speckled layers in lower parts.
- Ferralsols cover 61.85% of the area of Phu Quoc mainly on hill and mountainous areas.
- The leftover 0.175% is other soils.

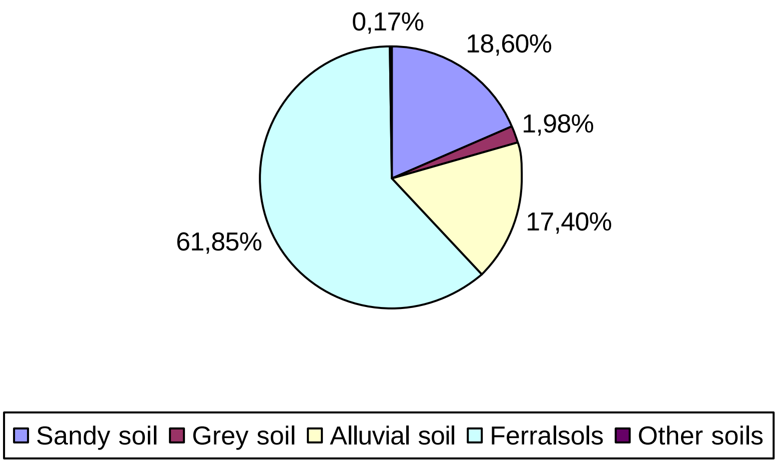


Figure 3-4: Soil types distribution at Phu Quoc island

3.1.4.2 Forest

Phu Quoc Island has around 37000 ha of forest (of which 31422 ha is national restricted forest) including some of high quality woods and medicine plants. This is also the habitat of valuable and rare animals. At Phu Quoc, the forest has an important role for the fresh water supply and attraction of tourist (variety of landscape); it is also important for study and research activities on rare species.

From the total surface area of 56,200 ha of Phu Quoc island, the former Nature Reserve (called Dao Phu Quoc) of 5,000 ha was transformed in 2001 in National Park of Phu Quoc. The total surface of the new Nation Park is 31,422 ha comprising a strict protection area of 8,786 ha, a forest rehabilitation area of 22,603 ha and an administration and services area of 33 ha. The aim of the National Park is the conservation of island forest including valuable wood species like Hopea sp. (BirdLife International, 2004).

3.1.4.3 Mineral Resource

The mineral resources at the island are not rich. Currently, only 7 types of minerals are discovered (black rock, stone, brick clay, kaolin, glass sand, sandy soil, and late rite).

3.1.4.4 Water

With high rainfall and high density of rivers and canals (0.42 km/km^2) Phu Quoc has an abundance surface water resource. However 80% of the rainfall is in the rainy season and most of the rivers are short and have a high slope, so that the rain water goes quickly to the sea.

The shallow groundwater exists everywhere on the island and serves as the main water supply in the dry season. The deeper groundwater resources (30 m under ground) are less in the North of the island than those in the South.

3.1.4.5 Marine Resource

The Phu Quoc shoreline is not deep. At 100–500 m from the seaside, the water depth is only 1–3 m on East side and 4 m on the West side of the island. Only boats of 100–200 Mg can access the sea port. This sea area is the great potential fishing ground of Vietnam with a reserve of 0.5 million tons of sea-creatures. According to preliminary estimation more than 200,000 Mg can be exploited annually, the current annual catch is only 50,000 Mg.

The seaside at the West of island has many nice beaches that could be developed into a centre of tourism with sea sport activities.

3.1.5 Social and Cultural Aspects

3.1.5.1 Population

In 2005, 88,304 inhabitants were living in 18,792 households on Phu Quoc. Thus, the average density is about 144 persons/km². Duong Dong town has the highest population density of 1,705 persons/km², second highest is An Thoi town with a density of 621 persons/km². The natural population growth rate is 1.7%/year, but the physical population growth rate is much higher. A lot of Phu Quoc's inhabitants today came from other areas of the nation to work in the island's expanding fishing industry.

Of the 88,304 inhabitants of Phu Quoc, Kinh people comprise 97.04%. The minority of the population consists of Chinese (1.98%), Khmer (0.92%) and 0.06% others.

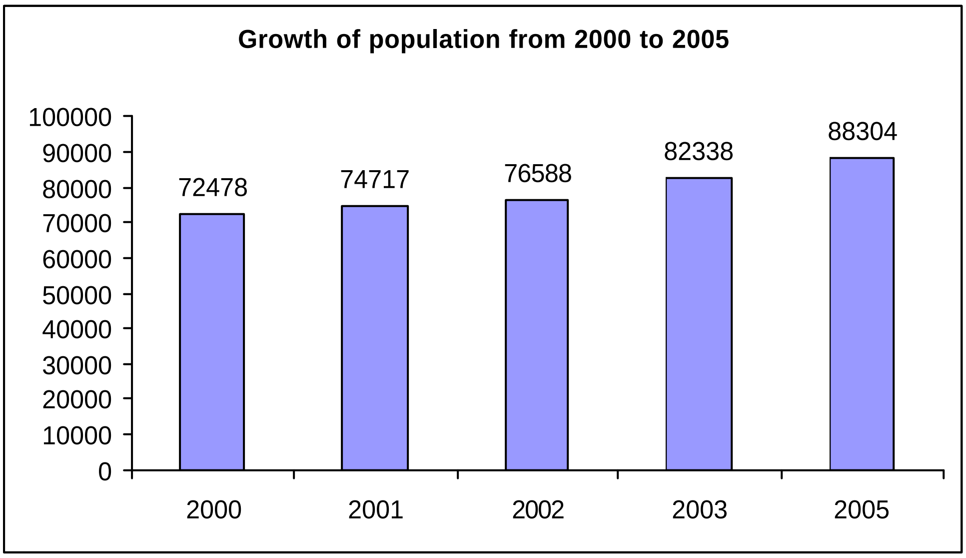


Figure 3-5: Population of Phu Quoc from 2000–2005[4]

The age structure in Vietnam indicates a very young population: 27.9% between 0-14 years, 66.4% between 1-64 years and 5.8% over 65 years, with a median age of 25.5 years (World Factbook, 2005 estimation). The Vietnamese population has also one of the highest growth ratios from Asian countries, although in the last years the growth ratio was slightly decreasing (1.49% in 2000, 1.45% in 2001, 1.43% in 2002, 1.29% in 2003, 1.30% in 2004, 1.04% in 2005; WORLD FACTBOOK, 2005). Phu Quoc Island shows a high increase in population number over the past year, mainly due to the governmental politics in the region and continuously improving living conditions. An average increase of 3.2% was calculated for the period between 2000 and 2005 and an estimation of 5.3% was made for the following years (see Figure 3-6).

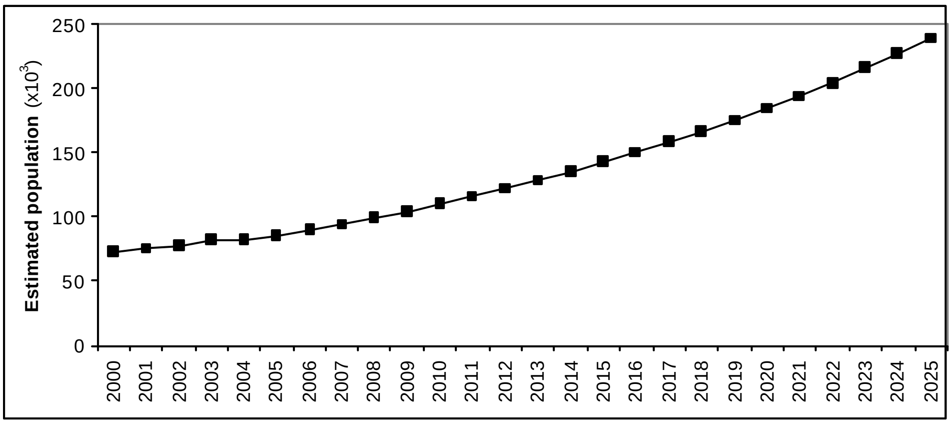


Figure 3-6: Forecast of population growth on Phu Quoc island (2000 – 2025)[5]

The population of Phu Quoc in 2005 was about 85,000 persons and the estimated number for 2025 is 238,700 considering a constant growth ratio of 5.3% per year (estimation based on: Department of Public Construction 2005).

[4] PHU QUOC DISTRICT 8/2004

[5] Department of Public Construction 2005, adapted

3.2 Legislative Aspects

3.2.1 Development Politics

The legal rationale for the development of biogas power plant is mentioned in the development policies of Phu Quoc Island as follows:

Table 3-1: Vietnamese laws and regulations related to development politics

No.	Name of document - date of issue - issuing authority	Contents
1	Decision No. 178/2004/QD-TTg dated 05-10-2004 by the Prime Minister of the Government	This decision approved the Master plan for development of Phu Quoc Island in Kien Giang province for the period up to 2010 and outlook to 2020 Objectives of development: Fast development of economy, making the island a regional and international tourist place with high quality services, attracting many foreign tourists. By 2010: establishment of some tourist areas, attracting about 300-350 thousands of tourists/year. By 2020: Phu Quoc becomes tourist and ocean ecological tourist centre, attracting about 2-3 million tourists /year.
2	Decision No.1197/Q§-TTg dated 09-11-2005 by the Prime Minister of the Government.	Decision on approval of general planning on construction of the island Phu Quoc, Kien Giang up to 2020, includes: 1. Scope of planning: 2 towns and 7 communes. 2. Objective: Phu Quoc becomes ocean ecological tourist centre with high quality, trade and service centre of the region, the whole country and international. 3. Population: by 2010 population is about 110,000 – 120,000 people, by 2020 about 200,000- 230,000 people. 4. Land: 56324ha, 5. Orientation for development of landscapes, zoning for concrete development targets. 6. Orientation on development of infrastructure: targets of electricity supply for different end-uses, power capacity demand up to 2010 and 2020, anticipation of power generation development, encouraging investment in renewable electricity projects with environmental protection. Water discharge and environmental hygiene: construction of system to collect waste water; construction of concentrated waste treatment area. 7. Anticipation of prioritised development programs for next 5-10 years including expansion of Dong Duong power plant.

No.	Name of document - date of issue - issuing authority	Contents
3	Decision No.2716/QD-UB dated 22-8-1998 by the People Committee of Kien Giang province.	Decision on establishment of Public Project Management Board of Phu Quoc district with main functions and duties to keep environmental hygiene, collection and transport wastes etc.

3.2.2 Regional and Local Planning

All project plans at Phu Quoc have to strictly follow the Master Plan to develop this island until 2020. Some framework conditions should be referred to:

- The conclusion from Political Bureau in the Announce 85-TB/TW at October 30th 2002 on "Direction, Mission, and Solution for the economy and society development of the Mekong Delta in 2001 ÷ 2010".
- The Decision 178/2004/QD-TTg signed by the Prime Minister on October 05th 2004 in "General development of Phu Quoc district, Kien Giang province until 2010 and vision for 2020".
- The Suggestion from the Minister of the Ministry of Construction in the paper 36/TTr-BXD at June 7th 2005 on "Master plan for Phu Quoc until 2020".
- The Decision 1197/QD-TTg signed on November 9th 2005 by the Prime Minister on "Master plan for Phu Quoc district, Kien Giang province until 2020".

In order to promote the development of Phu Quoc, on October 05th 2004, the Prime Minister has signed the Decision 178/2004/QD-TTg on "General development Phu Quoc district, Kien Giang province, until 2010 and vision to 2020".

In accordance to the decision 178, the development in Phu Quoc Island has to focus on some objectives such as:

- promoting the opportunities of the natural seaside to construct a high quality eco-tourist centre that can attract annually 300,000-350,000 tourists (by 2010) and 2-3 million tourists (by 2020); and investing into the human resource working in tourism. Such a development will upgrade the living standard and create jobs for locals.
- development of service sector to ensure the implementation of other developments and the changing economic structure. In the first phase, Phu Quoc will concentrate on the development of service sectors that support tourist development.
- sustainable development of 6600 ha agricultural land (3000 ha cashew, 1200 ha pepper, 1000 ha fruits, 300 ha vegetable and 270 ha coconut) to produce clean, high quality products serving for eco-tourism; stabilizing the forest area at 68-69% of natural island area, protecting the biodiversity of the pristine forest.

- combining the development of aquaculture with the development of tourism: focusing on the production of specific sea-products to serve for tourist and for export, establishing fish breeding centre to supply fry for the Mekong delta.
- development of a clean industry to create jobs and produce goods to serve for tourism, establishing some small industrial zones (2-5 ha each) near the residential area.
- Development of the traffic networks including road, over-rail, telpher, airport and seaport.

In order to archive all of the above objectives, the Phu Quoc government set up two development periods as the followings:

- From 2005 to 2010: starting to build the infrastructure systems to serve for short term demands, making the master plan for comprehensive development of Phu Quoc and some other specialization plans; calling for project's investment.
- From 2010 to 2020: finishing the development according to the master plan, finishing all main development projects at Phu Quoc; completing the construction of seaport, the water supply network and the high-class public service works; completing the high quality tourist zone, the international centre of business and trade.

On November 11th 2005, the Prime Minister signed the Decision 1197/QD-TTg on "Making master plan for Phu Quoc district, Kien Giang province, to 2020".

This decision again emphasised for Phu Quoc to become a high-quality sea and island ecotourism centre and a place for commercial and service exchanges with national, regional and international markets.

The development of the Duong Dong, Sao, Khem, Truong, and Dai beaches will be among the top priorities in the tourism development plan. Duong Dong town will be the administrative, service, commercial, industrial and tourism centre of the island.

An 800 hectare airport will be built to serve for 2.5 million passengers each year (2020). The airport is expected to be put into operation by 2010.

The government encourages all domestic and foreign economic sectors to invest in the development the island. The government's fund will prior to this invest into the infrastructure of the island.

3.2.3 Energy Politics and Relevance of Renewable Energy

Energy policies of Vietnam which have positive impacts on development of biogas power plant on Phu Quoc are as follows:

Table 3-2: Vietnamese laws and regulations related to (renewable) energy

No.	Name of document - date of issue - issuing authority	Contents
1	Prime Minister Decision No.22/1999/QD-TTg (1999)	Ratified the Proposal on Rural Electrification; stipulates that rural electricity supply will use national power grid and off-grid least cost based power projects; provincial people committees are responsible for preparing power development plans & development and management of renewable energy; encourages IPP investment at 5000 kW capacity

No.	Name of document - date of issue - issuing authority	Contents
2	Prime Minister Decision No.294/2001 (2000)	Issued to approve Rural Energy Project
3	Prime Minister Decision No.95/2001 (2001)	Approved the *Master Plan for Power Development in Vietnam for the period 2001-2010* with prospective consideration up to 2020; provides guidelines for other economic sectors in investment and operation of small and medium hydro power stations; classify the areas to be supplied with electricity from national grid or by local sources such as diesel units, wind, solar energy, geothermal energy sources
4	Government Decree 45/2001/ND-CP	Electricity operation and usage allowing rural electric network infrastructure to be invested jointly by the State and people, and central and local authorities under different scheme of management and ownership; allows loans at lower interest rates, tariff ceilings, pricing, tax reduction, diversification of investment, power generation projects
5	Government Decree 74/2003/ND-CP (2003)	Imposes administrative penalty in electricity activities
6	Government Decree No. 102 on Energy Saving & EE	Study the development of energy saving & EE projects; promote environmental protection & overcome environmental problems raised from energy production and use
7	Tax incentives (as of 2003)	New projects to receive a complete exemption from tax on profits during 1st two years of operation & 50% exemption during the next 2 years; preferential income tax rates of 15%, 20% or 25% in lieu of the normal income tax rate of 30%; full exemption of tax for use of EE technology for power plants, electrical networks & solar energy usage
8	Electricity Law (issued on 14/12/2004 according to order No. 24/2004/L-CTN by the President of the State)	Improve legislation and establish stronger legal framework for electricity activities in general & rural energy development and electrification. The clauses related to priority for development of renewable energy include: For development of renewable energy projects in general: Promoting exploitation and use of renewable energy resources for electricity generation. Projects of investment in power plants using new and renewable energy resources are given incentives in investment, electricity tariff and taxation preferential under the guideline of the ministry of Finance. For rural, mountainous and island areas: Attracting all resources for development of electric power infrastructure, speed up electrification process in rural, mountainous and island areas. Makes favourable conditions for people to use electricity for living and production in remote mountainous areas, ethnic minorities, especially socio-economic difficult areas. Organizations, individuals in all economic sectors acting in electricity generation, distribution and doing business in rural, mountainous, island areas with socio-economic difficulties and special difficulties are given preferential

No.	Name of document - date of issue - issuing authority	Contents
		policies in terms of investment, financing and other privileges according to law on investment encouragement. Encourages organizations, individuals to invest in construction of power network or local power stations using new, renewable energy to supply electricity to rural, mountainous and island areas.
9	Draft National Energy Policy (2004)	development of energy infrastructures & ensure adequate, stable and long-run energy supply; energy development focusing on environmental protection & sustainable development; economical and efficient use of energy; carry out measures in favour of EE & conservation in high buildings, apply demand-side management (DSM) and energy supply management; promote rural energy policy; enhance international cooperation; improve legal framework & implement market-oriented power reform

3.2.4 Building Law and Regulations

In Vietnam, the law in construction is a collection of documents that is promulgated by the government to adjust the issues in economy, social sector, technology and art that arise from and during a construction process (included new buildings, reconstructions, repairs), as well as basic construction fields (industry, infrastructure) and civil constructions (the house).

This law shall apply to domestic organizations and individuals as well as foreign organizations and individuals investing into constructions and engaging in construction activities within the territory of the Socialist Republic of Vietnam. Is an international treaty signed or acceded by the Socialist Republic of Vietnam to contain provisions which are different from those in this law, the provisions of such international treaty shall apply.

In addition, during the investment and construction process the investor, tender and constructor has to follow the obligations issued in these regulations:

Table 3-3: Vietnamese laws and regulations related to building and construction

No.	Name of document - date of issue - issuing authority	Contents
1	The Inter-Ministry Circular 04/TTLB signed on September 10th 1996 by the Ministry of Construction, the Ministry of Planning and Investment, the Ministry of Financial	Guidelines on Construction Management

No.	Name of document - date of issue - issuing authority	Contents
2	Decision No 1242/1998/QD-BXD dated on November 25th 1998 by Ministry of Construction	Promulgating the norm of cost estimation for basis construction
3	Decree 52/1999/ND-CP signed on July 8th 1999; Decree 12/2000/ND-CP signed on May 5th 2000 and Decree 07/2003/ND-CP signed on Jan. 1st 2003 promulgated by the Government	The regulations on investment and construction a work in the territory of the Socialist Republic of Vietnam, including: • Conditions for beginning a work • Projects that need to apply for construction permit • Authorization of issuing construction permit • Duration for issuing construction permit • Capacity of tender • Approval of tendering result and the contract • Needed procedure after construction
4	The Decision 29/1999/QD-BXD signed on October 22nd 1999 by Ministry of Construction	Regulation on Environmental Protection in Construction field such as: • Making EIA for construction work • Protection of water, air and so on, during construction procedure.
5	Circular No 109/2000/TT-BTC dated on November 13th 2000 by Ministry of Finance	Guideline on submitting and receiving the fee on investment assessment activities.
6	The circular 08/2003/TT signed on July 9th 2003 by Ministry of construction	Guideline on the content and management the comprehensive contract design-equipment supply-construction (EPC)
7	The Decision 19/2003/QD-BXD signed on July 13th 2003 by Ministry of Construction	Concrete regulations on capacity of construction consultant and building works including: • Requirement on institutional capacity of project making organization • Requirement on capacity of project management board • Requirement on capacity of tender on construction survey • Requirement on capacity of tender on design • Requirement on capacity of tender on construction • Requirement on capacity of tender on construction supervision • Requirement on capacity of main tender • Requirement on capacity of comprehensive tender
8	Decree No 709/QD-NLDK dated 3/4/2004 by MOI	Guideline Draft for Economic - Financial analysis and ceiling electricity purchasing and selling price for investment project of power sources.

According to the Decree 52/1999/ND-CP all electric production projects with a total investment cost over 400 billion VND would be ranked in group A. Therefore, the project on “production of renewable energy from organic waste and biomass by biogas plants at Phu Quoc” with the estimated cost of 38.51 million € (≈ 750 billion VND)[6] will belong to group A. This project has to be submitted to the Prime Minister for approval. In the case where some overseas companies share the investment cost, the investors have the responsibility for the economic efficiency. Besides, the current regulations also require all project owners to submit documents on assessing the construction planning, architectural options, applied construction technology, land use, environmental protection measures, fire prevention and social aspects of the construction project to Ministry of Planning and Investment (MPI) for assessment. The result will be issued 60 days after the MPI has received all required documents.

3.2.5 Environmental Protection Law

The first Environmental Protection Law in Vietnam was approved by the National Assembly on December 12th 1993. This law concretized the article 29 of Vietnamese Constitution (1992) on the regulation of activities linked to environmental aspects. In order to cope with the new situation, this law is compiled again and approved by National Assembly in November 2005. The new law has taken its effect from June 2006.

Similar to the Construction Law, all projects which process in Vietnam have to following all articles mentioned in the Environmental Protection Law. In addition, some regulations should be referred to during preparation and implementation of the project, they could be:

Table 3-4: Vietnamese laws and regulations related to environment

Name of document - date of issue - issuing authority	Contents
Circular No 276/TT-MTg dated on March 6th 1997 issuing by Ministry of Science-Technology and Environment (MOSTE)	Guideline on environmental pollution control at the factories after having the approval on environmental impact assessment.
Circular No 490/1998/TT-BKHCNMT dated on April 4th 1998 issuing by Ministry of Science-Technology and Environment (MOSTE)	Guideline on making and assessing the environmental impact assessment of investment projects.
Circular No 55/2002/TT-BKHCNMT dated on July 23rd 2002 issuing by Ministry of Science-Technology and Environment (MOSTE)	Guideline on technology and environmental assessment of investment projects. Stipulating the projects that have to be assessed. Contents of environmental assessment: sources of

[6] Reference: "Planning of Electric Supply at Phu Quoc until 2010, vision to 2020", page III-5: maximum power need of Phu Quoc at 2020 is 88,844 kW. Then at page of V-5, they estimate the investment cost for a Diesel generator plant is 350USD/kW if use DO or 700 USD/kW if use HFO. From that an average value is 525 USD/kW.
The total investment costs for Diesel generator plant: 88,844 kW x 525 USD/kW = 46,643,000 USD = 38,510,000 EUR = 750,000,000,000 VND

Name of document - date of issue - issuing authority	Contents
	pollutants, types of pollutants (liquid, gas, solid) created during production process, implicit environmental hazards, treatment measure to minimize the negative impacts.
TCVN 5949 : 1998	Acoustics. Noise in public and residential areas. Maximum permitted noise level.
TCVN 5939 : 1995	Air quality. Industrial emission standards. Inorganic substances and dusts
TCVN 5940 : 1995	Air quality. Industrial emission standards. Organic substances
TCVN 6991 : 2001	Air quality. Standards for inorganic substances in industrial emission discharged in industrial zones
TCVN 6994 : 2001	Air quality. Standards for organic substances in industrial emission discharged in industrial zones
TCVN 6992 : 2001	Air quality. Standards for inorganic substances in industrial emission discharged in urban regions
TCVN 6993 : 2001	Air quality. Standards for inorganic substances in industrial emission discharged in rural and mountainous regions
TCVN 6995 : 2001	Air quality. Standards for organic substances in industrial emission discharged in urban regions
TCVN 6996 : 2001	Air quality. Standards for organic substances in industrial emission discharged in rural and mountainous regions
TCVN 5945 : 1995	Industrial waste water. Discharge standard
TCVN 6980 : 2001	Water quality. Standards for industrial effluents discharged into rivers used for domestic water supply
TCVN 6982 : 2001	Water quality. Standards for industrial effluents discharged into rivers used for water sports and recreation
TCVN 6983 : 2001	Water quality - Standards for industrial effluents discharged into lakes used for water sports and recreation
TCVN 6984 : 2001	Water quality - Standards for industrial effluents discharged into river used for protection of aquatic life
TCVN 6985 : 2001	Water quality - Standards for industrial effluents discharged into lakes used for protection of aquatic life
TCVN 6986 : 2001	Water quality - Standards for industrial effluents discharged into coastal waters used for protection of aquatic life
TCVN 7440 : 2005	Standard on the thermo-electricity industrial waste
Decision No 07/2005/Q§-BTNMT dated September 20th 2005 by Ministry of Natural resource and environment	Decision by Minister of Natural Resources and Environment on the compulsory application of Vietnam's standard **TCVN 7440**:**2005** on the thermo-electricity industrial waste

Note: TCVN = Vietnamese standard

3.2.6 Ownership and Operating Law

Interviews in a participatory workshop held in December 2004 revealed that both, the provincial government of Kien Giang as well as the local government of Phu Quoc highly support the introduction of renewable energy and waste treatment technologies on the island. The establishment of environmental sound practices in the field of energy production and waste management is regarded crucial to ensure a future sustainable development.

The responsibility for production, distribution, and sale of electricity on Phu Quoc lies with the Electric Power Company 2 in Kien Giang province, regional subsidiary of the national state-owned utility Electricity of Vietnam (EVN). The initiative to complement the island's electricity system with renewable energy technologies was received by the Electric Power Company 2.

The operational safety regulations are mentioned in the documents below:

Table 3-5: Vietnamese laws and regulations related to ownership and operating

Name of document - date of issue - issuing authority	Contents
Safety regulations on design electric power plants, electric grid line of Ministry of Electricity -1984 (Book No 1: design of electric power plant and electric power station) issued along with the decision No 25 DL/KL of Ministry of Electricity (October 22nd 1985)	General requirement for the person who directly manages and operates the electric power plant and power station that has the voltage above and under 1000 V (health status, skill, training…) Requirement of the person who take the responsibility on safety of the plant his/her authority and duty Equipment operation procedures Equipment that have to be used when contacting with electricity Measure to ensure the safety at work
Decision No 235 QD/LD of Ministry of Labour and National committee on Science and Technology	Promulgating the safety requirement for boilers
Safety standard for boilers (QPVN 23-81) issued on Sep. 05th 1981.	Requirement on safety produce and use of boilers, including: • Requirement on boiler installation for safety use • Technical testing of new boiler • Periodical testing and hydraulic checking of in operation boiler • Extraordinary testing of boiler (for boiler that was not used more than one year, and boiler that was moved or repaired) • Requirement on the skill of the operational worker and qualification of technician

Name of document - date of issue - issuing authority	**Contents**
Decree No 06/CP dated on October 20th 1995 of the Government	Concretizing some articles in the Labour Law on labour safety and hygiene in work.
Decree 110/2002/ND-CP dated December 27th 2002 of the Government	Modifying and supplementing some articles in decree 06/CP of the Government
Circular No 23/2003/TT-BTLDTBXH dated on November 3rd of Ministry of labour-wounded soldier and society	Stipulating the list of machine and equipment that need to register for technical safety assessment (boiler with the working pressure over 0.7 kg/cm^2, boiler with the temperature of substance more than 115^{o}C
Circular No 03/2003/TT-BTC dated on January 10th of Ministry of Finance	Stipulating the fee for technical safety assessment of machine and equipment
Electric Power Law ratified by National Assembly on December 3rd 2004	Regulations on the activities in the field of electric power: The responsibility of the generation unit on the complying with the approved procedure on: operation power plant, measure in case of an accident happening Regulations on electricity generation, equipment for fire prevention and protection, emergency exit entrance, lighting, alert board

3.2.7 Legislative Restrictions

The results of the BiWaRe project and RENEW project revealed that there is no restriction on the production of renewable energy from organic waste and biomass by biogas plants.

The interviews in a participatory workshop held in December 2004 revealed that both, the provincial government of Kien Giang as well as the local government of Phu Quoc highly support the introduction of renewable energy and waste treatment technologies on the island. The establishment of environmental sound practices in the field of energy production and waste management is regarded crucial to ensure a future sustainable development.

The framework conditions on the island of Phu Quoc were found to be very favourable for the application of renewable energy by biogas processes. The prevailing relatively high electricity tariff (compared to 5.1 € cents/kWh on the mainland) is expected to provide attractive returns for the project. The production of bio-fertilizer will result in additional revenue that further improves the project profitability.

However, there is some legal limitation that should be considered while writing the project proposal:

Phu Quoc Island is not included in the list of rural, mountainous, and island area that will get the incentive measures for the activities on generation, distribution and trading electricity (as mentioned in article 60 of Electric Power Law).

In order to get the credit from the government for an investment and development project the investor should consider the Decree 106/2004/ND-CP signed on April 1st 2004.

- The article 3 mentions the support for projects able to get pay-back, but in order to get this support the project has to sell the product at an acceptable price
- The article 8 mentions that the government only locates the credit for the projects in the programs that were approved by the government. The last date for being put on the list of these programs in the period of 2006-2011 is December 31st 2005. This means that the project on production of renewable energy from organic waste by biogas plant at Phu Quoc is late to apply.

3.3 Economic Framework at Phu Quoc

3.3.1 Infrastructure

The infrastructures like hospitals, education and the communication network were invested into to satisfy the demand of the local inhabitants. According to the Ministry of Planning and Investment, 616.7 billion VND will be allocated to implement four key projects on Phu Quoc Island in the southern province of Kien Giang. With these projects, two roads linking Duong Dong to Cua Can (12.6 km) and Suoi Cai to Canh Gau (17.9 km) will be upgraded and a new road linking Bai Thom to Ganh Dau (33 km) and An Thoi port will be built.

3.3.2 Industry

The industry sector could be divided into three main categories: Exploiting industry, Processing industry and water, electricity supply. The number of companies and factories increased steadily during the period of 2000-2004 but decrease in 2005.

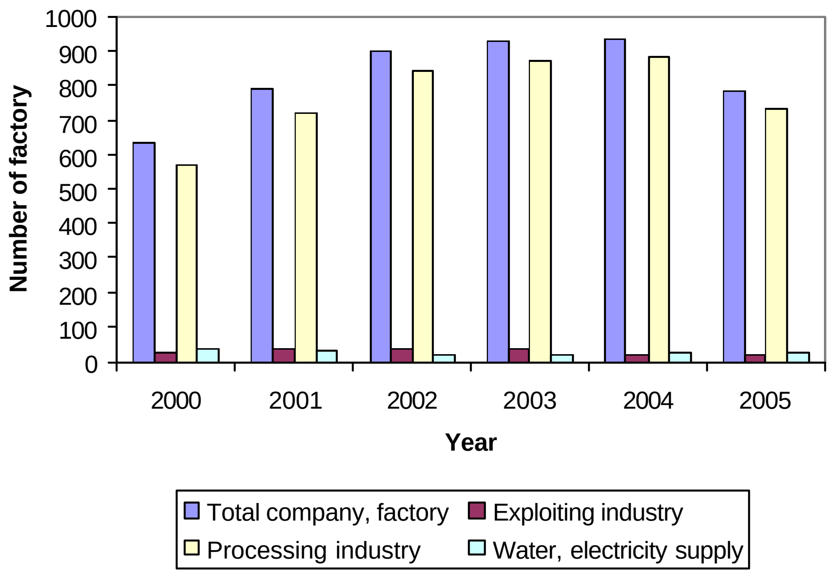


Figure 3-7: Changes in number of factories during the period of 2000-2005

3.3.3 Agriculture and Forestry

The agricultural sector plays a vital in Phu Quoc's economy. There are four main types of perennial plants at Phu Quoc: pepper, cashew, coconuts and fruit trees. Except for pepper these plants have low yield due to poor investment especially on seeding plants. Recently, because of a decrease in the price of pepper the area in which pepper is grown quickly decreased. The main part of the annual crop is now fruit.

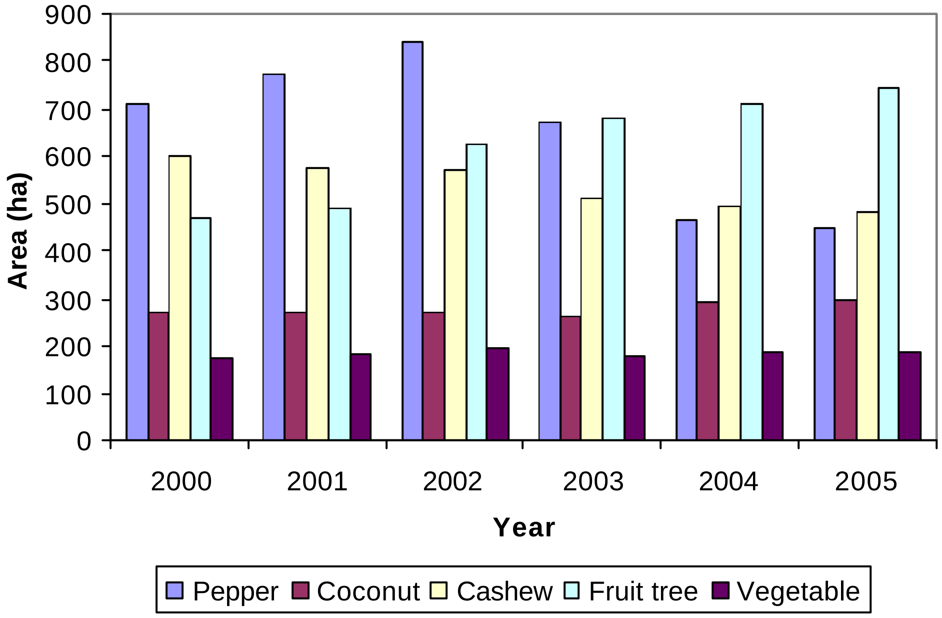


Figure 3-8: Area of major agricultural crops at Phu Quoc

Figure 3-9: Pepper garden, suggar cane and banana growing on Phu Quoc (IKrW, December 2005)

The results are mostly sold directly on daily markets as shown in Figure 3-10. Just a small amount is sold to the mainland.

Figure 3-10: Fresh fruits and vegetables are sold on street markets (IKrW, December 2005)

A large area of forest was planted on Phu Quoc Island in the year 2000, less was planted during the period of 2001-2003, more again in 2003-2004 and the area of forest planted again decreased in 2005 as shown in Figure 3-11.

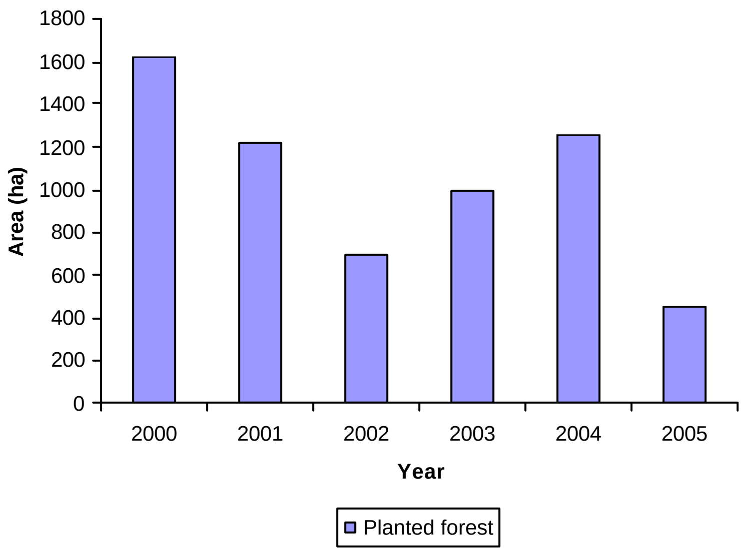


Figure 3-11: Area of planted forest on Phu Quoc island

Residues from agriculture and forestry are mostly suitable for the generation of energy by biogas plants or biomass combustion plants. Thus, they play an important role according to the feasibility of plant-implementation. The following table represents a selection of the most relevant substrates. If organic substrates are available, which are not mentioned here, consultation of an expert is required.

Table 3-6: Suitability of substrates from agriculture or forestry for biogas or biomass combustion processes

Substrates	Suitability	
	Biogas process	Biomass combustion
Agro based crop substrates		
Algae	+	+
Barley straw	(+)	+
Beet tops	+	+
Beet tops, (sugar beet)	+	+
Beet, sugar beet	+	+
Beet, (fodder)	+	(+)
Blood meal	+	+
Cane trash	+	+
Clover	+	(+)
Coco bean shells	-	+
Elephant grass	(+)	+
Flax	(+)	+
Grass	+	-
Grass silage	+	-
Hay	+	+
Hemp	+	-
Maize silage	+	-
Maize straw	+	+
Oat straw	(+)	+
Peanut husk	-	+
Potato tops	+	+
Rape straw	(+)	+
Rapeseed shred	+	(+)
Reed		+
Residual wood (common)	-	+
Bark	-	+
Rice husk	-	+
Rice straw	(+)	+
Rye straw	(+)	+
Sunflower leaves	+	-
Water hyacinth	+	+
Wheat	+	(+)
Wheat straw	+	+
Animal husbandry		
Cattle manure	+	-
Cattle manure (with straw)	+	-
Chicken manure	+	-
Chicken manure (with straw)	+	-
Horse manure (with straw)	+	-
Pig manure	+	-
Pig manure (with straw)	+	-
Sheep manure (with straw)	+	-
Cattle manure	+	-
Cattle manure (with straw)	+	-
Chicken manure	+	-
Chicken manure (with straw)	+	-
Forestry based residues		
all types of wood and residues (e.g. saw dust)	-	+

3.3.4 Aquaculture, Fishery and Fish Processing

Sea product exploiting is the main production activity attracting 40% of the labour force and contribution around 19% GDP of the whole district. Currently, the people of Phu Quoc own 2430 fishing boats. However there has been no adequate investment in off-shore fishery.

Figure 3-12: Facts of sea product exploiting activity at Phu Quoc

Figure 3-13: Fishing boats on Phu Quoc island (IKrW, December 2005)

Phu Quoc is famous worldwide for its traditional fish sauce produced in hundreds of fish sauce workshops, especially in the North of the island.

3.3.5 Tourism and Service

Tourism and service are fast growing sector of Phu Quoc. Due to the beautiful landscape consisting of pristine forest and nice beaches, Phu Quoc has a great potential for eco-tourist development. The number of tourist increases quickly and also their period of staying. The fast increasing of this sector will create a high pressure for electricity and water supply sector.

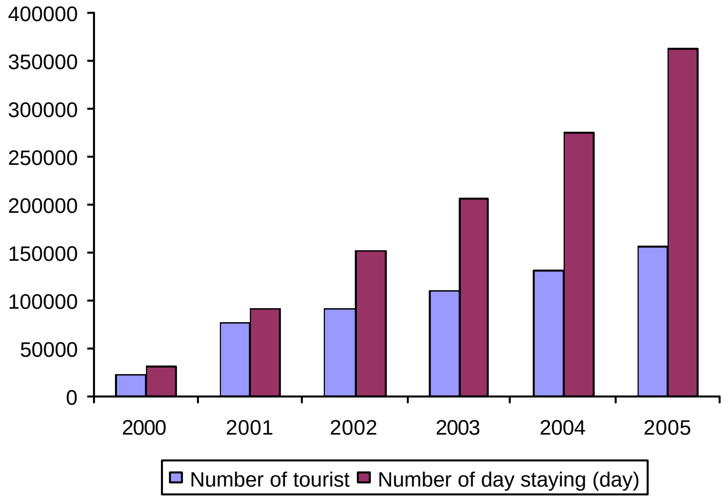


Figure 3-14: Facts of tourism sector at Phu Quoc

The estimated number of tourists for 2005 is 220,000 and this number is expected to rise up to 500,000 by the year 2011 (Phu Quoc District Report, 2004). Due to the limited availability of accommodation facilities planned for Phu Quoc starting with 2010, when most of the new hotels will be ready to receive guests, a prognosis for the period 2010-2025 is difficult. One can assume a constant number of tourists (about 500,000) will visit Phu Quoc every year, but a more precise forecast will require an additional study.

3.3.6 Economic Development

From 1991 until now Phu Quoc's economic growth rate was high. The economic structure has changed strongly following the industrializing trend of the whole nation the values in industry and service are quickly increasing. From 2000-2004 the average economic growth rate has been 12.9% per year. In the year 2004 it decreased to 8.99% and recovered again in 2005. However, Phu Quoc started of very poor and it is still a poor district.

The income of the people at Phu Quoc is higher than that of people in other districts of the Kien Giang province. But the cost of living on Phu Quoc is also higher than those of other districts.

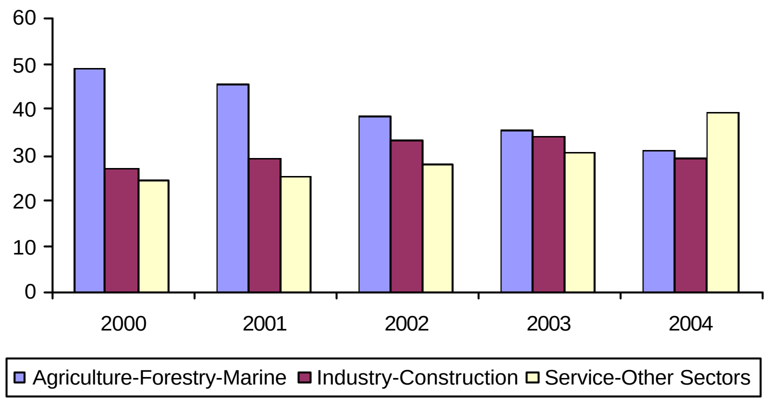


Figure 3-15: Changes in the economic structure of Phu Quoc

As shown in Figure 3-15, the economic structure is changing according to the industrialization trend of the whole nation.

3.4 Energy Sector at Phu Quoc

3.4.1 Current System of Power Generation

With a distance of 115 km from Rach Gia town and 45 km from Ha Tien town, a connection of the electricity network on Phu Quoc to the national grid is considered economically infeasible.

From 1995 to July 2004, Phu Quoc had one electricity plant with two DG-72 generators (from the former Soviet Union) and three CAT generators (from USA) that operate with diesel oil.

Figure 3-16: DG-72 generators in the old power plant and new power plant in Cua Duong, nearby Duong Dong

In July 2004, a new power plant with 5 generators was put into operation (see Table 3-7). This new plant is located at Cua Duong commune – 5 km northeast of Duong Dong town.

At first, two new sets manufactured by Mitsubishi (Japan) were installed and put into operation with the new Phu Quoc power plant in July 2004. They have a low fuel consumption (208 g DO/kWh) and run at base load, now. In general, the technical status of these two new units is good and ensures operation.

Three other generator sets of the brand CATERPILLAR (CAT 3412, CAT 3508 and CAT 3512) made in the United States of America, were transferred from the old to the new power plant and operate at peak load. They run with a higher fuel consumption (255-270 g/kWh).

Mitsubishi generators CATERPILLAR generators

Figure 3-17: Types of generators in Phu Quoc's new power plant (IKrW, December 2005)

Currently, the two DG-72 generators (Figure 3-16, nominal capacity: 1600 kW) were left at the old power plant to be provided for possible contingencies.

Table 3-7: Main technical parameters of Phu Quoc's new power plant

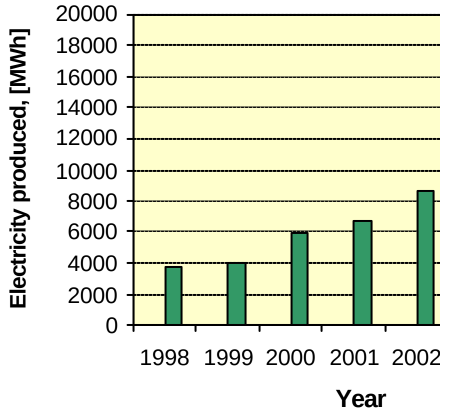
Machine type/ producing country	Mitsubishi Japan	Mitsubishi Japan	CAT-3412 USA	CAT-3508 USA	CAT-3512 USA
Nominal capacity (kW)	1500	1500	580	800	1020
Usable capacity (kW)	1500	1500	450	700	900
Operation since	July 2004	July 2004	-	-	Feb. 2002
Type of fuel	Diesel oil	Diesel oil	Diesel oil	Diesel oil	Diesel oil
Specific fuel consumption (g/kWh)	208	208	270	270	255

According to the typical daily load curve of Phu Quoc, the daily peak load is about 3700 kW. That means the maximal load factor of the power plant is 0.68. The nominal capacity of this electricity plant is 5400 kW in which the usable electric power is 5050 kW.

Total electricity production of the old and new Phu Quoc power plants in recent years has been increased. According to the data of the Phu Quoc power branch, electricity production is increased approx. 4.8 times from 1998 to 2004 (nearly 30%/year, see Table 3-8)

Table 3-8: Electricity production by diesel sets of Phu Quoc power plant

Year	1998	1999	2000	2001	2002	2003	2004
Electricity production (MWh)	3821	4072	5888	6711	8645	13699	18311



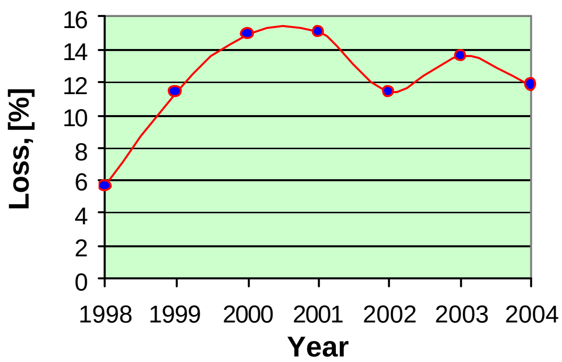
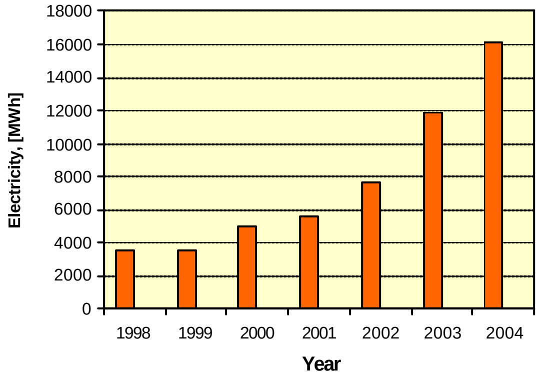
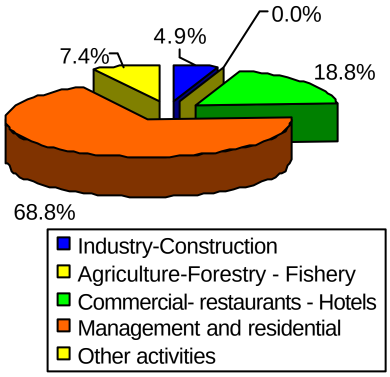


Figure 3-18: Phu Quoc Power plant - Electricity production and loss during 1998-2004



Electricity sale in Phu Quoc Power Plant - period 1998-2004



Electricity supplied to different consumers in Phu Quoc in 2004

Figure 3-19: Electricity production and sale in Phu Quoc power plant - period 1998-2004

In addition, some small independent generators with a total nominal capacity of 380 kW were also installed at rural areas not reached by the grid line (e.g. Ganh Dau or the quarter of Marine Military Zone 5).

3.4.2 Consumption and Demand of Electricity

Until the end of 2004, only Duong Dong town, An Thoi town and the four communes Duong To, Cua Duong, Cua Can and Ham Ninh have been supplied with electricity. Thus, only 8,114 of 18,791 households have electric power for daily activities in this island (43%).

In the period of 8 years, from 1996–2004, electricity sales at Phu Quoc strongly increased, by 33.7 times (from 497.12 MWh to 16,156.2 MWh). The average growth rate is 55%/year, broken down to 80 %/year in the period 1996-2000, 34 %/year in the period 2000–2004. In 2004 the average electricity consumption per capita is 198 kWh/person*year. Average electricity consumption for lighting is 136 kWh/person*year for the whole district. If calculated only for households that have electricity, then the electricity consumption is 114 kWh/household*month, equivalent to 300 kWh/person*year.

At present, Phu Quoc is supplied with electricity from new Phu Quoc power plant. The total electricity sales of Phu Quoc in the period of 1996–2004 are presented in Table 3-9.

These numbers do not reflect the real demand of electric power on Phu Quoc island, because some areas were not connected with the grid line. However, this table shows that the amount of electricity consumed has been quickly increasing in recent years, the average electricity consumption increased by 41.5% per year during period of 2001–2004 and it is likely that this trend will continue in the future.

The office-domestic sector is the biggest electricity consumption sector with an average growth rate of 34.2% from 2001–2004. The second biggest sector consuming electricity on Phu Quoc is the business-hotel-restaurant sector, but this sector has the highest average growth rate at 56.5% from 2001–2004.

Table 3-9: Electricity production and consumption in Phu Quoc in the period 1996-2004[7]

Year	Electricity Production (MWh)	Electricity sales (MWh)	In which				
			Industry-Construction (%)	Agriculture Forestry Fishery (%)	Services Restaurant Hotels (%)	Management Residents (%)	Other Activties (%)
1996		479.12	21.9		6.9	69.4	
1997		2,420.3	22.6		7.3	70.1	
1998	3,821.3	2,881.2	10.6		8.9	80.5	
1999	4,071.9	3,605.3	12.8		8.3	78.9	
2000	5,887.6	5,005.0	8.0		11.3	80.9	
2001	6,711.0	5,704.3	5.5		13.9	80.6	
2002	8,645.0	7,656.9	2.5	0.3	11.2	79.5	6.5
2003	13,699.1	11,845.5	6.4	0.07	15.0	72.4	6.1
2004	18,311.8	16,156.2	4.9	0.04	18.8	68.8	7.4

There is no clear growing trend in the industry sector as the amount consumed is still small in comparison to other sectors. Some ice-factories (freezing water to ice) are large customers. Thus, the consumed amount of electricity is highly depended on the production activities of these factories. The average electricity consumption growth rate for this sector in 2001–2004 is about 36.7%.

The total capacity of the power system of Phu Quoc district, including power plant of the district and independent power stations cannot meet the electricity demand. There was an extension plan for the power plant of Phu Quoc to be implemented in 2005.

3.4.3 Transformation of Electricity

The generators of Phu Quoc power plant generate electricity at voltage of 0.4 kV which is increased to 15 kV by 4 transformers located in the power plant. The step up transformers have inlet and outlet voltage of 0.4/15 kV. There is only one transformer which has additional outlet voltage level of 22 kV (Table 3-10).

Table 3-10: Step up transformers at Phu Quoc power plant [Source: PECC3]

No.	Specifications	Tran. 1	Tran. 2	Tran. 3	Tran. 4
1	Rated capacity	1000	1000	2500	4000
2	Installation year	1995	1995	2001	2004
3	Manufacturer	THIBIDI	THIBIDI	EMF	THIBIDI
4	Voltage (kV/kV)	0.4/15	0.4/15	0.4/15 (22)	0.4/15

[7] PECC3

3.4.4 Situation of Local Grid Line

The volume of power lines and substations of Phu Quoc as of December 2004 is presented in the following table:

Table 3-11: Volume of power lines and substations at Phu Quoc (December 2004)[8]

No.	Item	Unit	Volume
I	**Power lines**	**km**	
A	Medium voltage, in which		82.92
	1 phase lines		4.20
	3 phase lines		78.72
B	Low voltage (0.4 kV lines)		46
II	**Substations**		
	1 phase substations	Substations/kVA	64/1668
	3 phase substations	Substations/kVA	74/8825
III	**Electricity meters**	**Unit**	**6121**
IV	**Compensation capacitors**	**Quantity/kVA**	**4/1500**

Temporary electric pole

Electric network in Duong Dong

Figure 3-20: Electricity grid network on Phu Quoc island

3.4.4.1 Medium Voltage Grid Line

Total length of the medium voltage power network in Phu Quoc district is 83 km. This composes of mainly 3 phase conductors (94.9%) and of 1 phase conductors, which account for only 5.1%. The whole medium voltage network is overhead line.

There are 6,121 electricity meters installed in the common medium voltage power network of the district, mainly one phase meters.

The ratios between growth rates of total length of power network and electricity consumption in the years 2001 and 2004 are presented in the following table:

Table 3-12: The ratios between growth rates of total length of power network and electricity consumption in 2001 and 2004

Year	Length of medium voltage power network Electricity consumption [km/GWh]
2001	11.4
2004	5.13

Therefore the growth rate of medium voltage power network from 2001-2004 does not meet the increasing demand. So far, there is no development plan for medium voltage power network to the communes without electricity.

3.4.4.2 Low Voltage Grid Line

Unlike to the medium voltage power network, the radius of power supply by the low voltage power network is long, causing high voltage loss. Low voltage power network has many types of conductors with a small cross section area, constructed not in compliance with standards it does not ensure the required safety.

Total length of the low voltage power network in the area managed by Phu Quoc power branch is about 70 km. This network includes two sections: 3-phase lines (at voltage of 220/380 V) and 1-phase lines (voltage of 220 V). The total length of the 0.4 kV lines is 46 km as of December 2004.

Besides the quality of operation of the low voltage power network of Phu Quoc is very poor because it is too old and has been in operation without repairing or replacement for a long time.

3.4.5 Substations

In the power distribution network of Phu Quoc district there are 138 substations with total capacity of about 10,500 kVA. The loads of these substations are only about 35%. Most substations are operated at voltage of 15 kV.

Table 3-13 presents development of Phu Quoc power network through the ratio between total capacity of substations and electricity consumption.

Table 3-13: Ratio of total capacity of substations and electricity consumption in Phu Quoc district in 2001 and 2004[9]

Year	Total capacity of substations / Electricity consumption [MVA/GWh]
2001	0.75
2004	0.65

[8] PECC3

[9] PECC3

The above data indicate that from 2001 to 2004, total capacity of substations is increased faster than electricity consumption. According to the assessment of a study team of Power Engineering Consulting Company 3, the reason may be due to increase of concentrated loads that belong to commercial loads such as hotels and restaurants.

3.4.6 Price Tariff

Fuel used in the power plant is diesel oil which has a high price (522 US$/ton) and is affected by the fluctuation of the international market, therefore the electricity production costs are high. Because of the socio-economic development required of the island district and the need to comply with the united electricity tariff in the whole country, in recent years, the power sector had to compensate the loss of the electricity business at Phu Quoc. According to report of Power Company 2, in 2004 the power had to be compensated with 13.5 billion VND (equivalent to 854.4 thousand US$). The compensation needed in 2005 is anticipated to be higher.

In 2001, the electricity system at Phu Quoc is operated and managed by the Phu Quoc Power branch. They applied the price tariff for electricity as the following:

- Electricity use for lighting and domestic activities: 2000 VND/kWh for the first 100 kWh, from the 101st kWh the price is 2500 VND/kWh
- Electricity used for business and service sector: 3000 VND/kWh
- Electricity used for production activities: 2600 VND/kWh
- Electricity used for administrative sector: 2500 VND/kWh
- With this price tariff the Phu Quoc Power branch lost 190 million VND in 2001.

From 2002 the Power Company 2 (PC 2) became responsible for the electricity system and applied a new price tariff that was only half as expensive as the old one. The price tariff from January 1st 2002 was as follow:

- Electricity used for lighting and domestic activities: 1000 VND/kWh f
- Electricity used for business and service sector: 1500 VND/kWh
- Electricity used for production activities: 1300 VND/KWh
- Electricity used for administrative sector: 1250 VND/kWh

With this price tariff, in 2002-2005 PC 2 had to be subsidized, the average value of subsidy increased by 70% per year.

People living at the area which is not connected to the electricity network yet have to buy the electric at a higher price. At Cua Can, Bai Thom commune, they have to pay 30,000 VND for 1 fluorescent light (20 W) per month, but the electricity is just supplied from 6 PM to 10 PM each day. At Ganh Dau people have to pay 5,000–6,000 VND/kWh (equivalent to 38 UScents/kWh), even up to 9,000 VND/kWh in some places.

This is too high in comparison to the income of inhabitants and equal to 20 times of the ceiling electricity tariff set by the State for other rural areas in Vietnam.

Table 3-14: Annual subsidies for electricity sold on Phu Quoc

Year	Subsidy value (million VND)	Comparison with previous year (%)	Comparison with turnover (%)
2001	190		
2002	4,712	2,480	61
2003	8,782	186	72
2004	13,512	153	80
2005 (estimated)	23,833	176	102

The main reason is that the grid has not reached a good standard so that the electricity loss is high (11.8% in 2004). Besides this the cost for electricity generation with diesel generators is high. In addition, the grid line does not cover all parts of the island so that some people have to buy electricity from private, independent electricity plants with higher prices.

3.4.7 Future Development of Energy Demand

In November 9th 2005, the Prime Minister signed the Decision No. 1197/QD-TTg to approve *"The general plan of construction Phu Quoc district- Kien Giang province- to the year 2020"*. The decisions made where also concerned with the electric supply systems. In the first term, Phu Quoc would be built a gas-electric power plant and carry out a feasibility study on a possible connection of Phu Quoc grid line with the main land electric grid line using a undersea cable. In additional, Phu Quoc is encouraged to invest into electric supply from renewable energy source such as solar power, wind power and so on.

According to these decisions, the total of electric power supplied on Phu Quoc island has to reach 50 MW in 2010 and 150 MW in 2020. The anticipated electricity supplies for each of the main consumption sector are as follows:

- Domestic sector: 1500 kW/person*year
- Industry sector: 250 kW/ha
- Tourist sector: 2–3 kW/bed

3.4.8 General Potential of Renewable Energy

In general, electricity supply situation in Phu Quoc does not meet demand in terms of quantity and quality. In order to meet the electricity demand in the coming years, Electricity of Vietnam (EVN) together with other sectors has considered the alternative of electricity supply from the main land by underground cable lines through the sea. However, this alternative is too expensive compared to the option of local power generation. Therefore, in coming years, local electricity generation is considered as the only option, with diesel power generators as the main and renewable power such as solar, wind and biomass as additional sources.

3.4.8.1 Solar Energy

Phu Quoc Island is located in the tropical climate zone, with relatively high solar energy potential, average of 5 kWh/m^2*day. Total sunshine hours are 2200 hours/year. Solar energy on Phu Quoc is mainly exploited as heat source directly used for processing seafood or agricultural products which are exposed under the sun. Some PV photovoltaic systems are installed on Phu Quoc but they can provide only small share of electricity to households far from the power grid.

Advantage of solar electricity is no environmental pollution, no fuel cost but initial investment is high. Due to transport cost of equipment and materials from main land to island, the initial investment cost of home PV power system on Phu Quoc is still high and not affordable for the poor people living far from power grid. These equipments are mainly installed in the framework of domestic or foreign granted projects.

There is no statistic data available on number and total capacity of installed solar systems but the capacity from these power resources are always small, meeting only minimal demand this makes them not suitable for households which have the average living level on the island.

3.4.8.2 Wind Energy

Except for some areas on the island which have no wind in one season of the year, in general, wind potential on Phu Quoc is relatively high. However the fundamental investigation on potential of this energy resource is not available and there is no wind power system installed on Phu Quoc so far.

Through site survey, 3 potential sites considered suitable for the installation of power wind turbine are identified. The total capacity of wind turbines anticipated in the electric power planning for Phu Quoc island up to 2010 is 2.25-2.5 MW[10].

3.4.8.3 Small Hydropower

Phu Quoc has tropical, monsoon climate with average rainfall of 2,060 mm/year. However, due to local geological conditions, the surface water sources on the island are limited. The dry season on Phu Quoc is very severe with long draughts and shortage of water for plants. The small hydropower potential of Phu Quoc is limited and not yet exploited. It is anticipated that it will not to be used in the period from now up to 2010.

3.4.8.4 Agricultural & Forestry Residues

Agricultural residues of Phu Quoc include wastes from annual crops such as rice straws, rice husk, corn, sweet potatoes, cassava etc. vegetables and residues from fruit plants in gardens, wooden wastes from wood processing and household furniture production facilities, animal excrement and wastes from sea food processing facilities. In general these waste resources are dispersed, not concentrated.

[10] PECC3

Exploitation and use of agricultural and forestry residues for energy production at present are only performed with those types that can be burnt directly such as wood and crop residues. The technologies used are simple such as traditional cook stoves, which are inefficient and inconvenient. The modern biomass combustion technology for transformation of waste into energy is not yet applied. Even having high potential, there is not any power plant using biogas as fuel on Phu Quoc, so far.

3.5 Waste Management Sector at Phu Quoc

In the past, the environmental protection awareness of the people at Phu Quoc was not high. This situation leaded to environmental pollution around settlements, especially in Duong Dong town and An Thoi town. Nowadays, waste is on focus to be treated for the generation of (renewable) energy. Its suitability is shown in Table 3-15 below. The list of substrates represents only a selection of the most relevant substrates. If organic substrates are available, which are not mentioned here, consultation of an expert is required.

3.5.1 Solid Waste Management Unit at Phu Quoc District

The Phu Quoc district Public Work Management Unit was founded on August 22nd 1998 by the decision 2716/QD-UB of Kien Giang People Committee. It started its work on October 1st 1998. The main responsibilities of this Unit are:

- collecting and disposing solid waste
- managing the public light
- planting and taking care for the shading tree
- dredging the sewer system,
- and managing for the public cemetery.

Currently the total personnel in this Unit are 52. This includes 7 staff in management group (head, vice-head, accounting, and other staff) and 45 workers (street sweeper, solid waste collector, electric technician, driver, tree planter, etc.). All staff working with high discipline consciousness, enthusiasm but their specialist skills are limit so that the results are not so good.

3.5.2 Solid Waste Sources on Phu Quoc

The household waste from the towns Duong Dong and An Thoi constitutes the major part of the island's total waste production. The daily waste generation in semi-urban areas can be estimated at 0.53 kg per capita. In general, the quantity of residential or household waste in Phu Quoc is relatively large. Solid waste at Phu Quoc is generated by the following sources:

- household, business centre, market
- restaurant, hotel, park
- office, school
- factory, husbandry
- hospital, health care centre
- construction area

The waste comes from residential areas, restaurants and hotels etc. With increase of population and increasing numbers of tourists as well as people's living standards, the amount of waste is also increasing.

Table 3-15: Suitability of substrates from waste for biogas or biomass combustion processes

Substrates (municipal and industrial waste)	Suitability	
	Biogas process	Biomass combustion
Animal cadaver meal	+	+
Bagasse	-	+
Biowaste	+	+
Cereal mash	+	-
Clippings (sedge)	+	
Coco bean shells	-	+
Fat (from fat separators)	+	-
Filtration silica gel (beer)	+	-
Float fat	+	-
Flotation sludge	+	(+)
Foliage / leaves	+	(+)
Food waste	+	+
Fruit pulp (fresh)	+	-
Kitchen waste	+	+
Loppings	+	-
Market waste	+	+
Mash of apples	+	-
Mash of fruits	+	-
Molasse	+	-
Molasses mash	+	-
Oil seed residue (pressed)	+	(+)
Peanut husk	-	+
Pomace of apples	+	-
Pomace of fruits	+	-
Pomace of grape	+	-
Potato mash	+	-
Potato peel waste, raw	+	-
Potato pulp	+	-
Potato slop	+	-
Raps extraction residue	+	(+)
Rumen content (pressed)	+	-
Rumen content (untreated)	+	-
Sewage sludge	+	(+)
Slaughterhouse waste	+	(+)
Spent grains from beer	+	(+)
Spent hops (dried)	+	+
Stomache contents (pig)	+	-
Straw	(+)	+
Vegetable waste	+	+
Vinasse	+	-
Whey	+	-
Yard trimming	+	-

Hereby means: "+": suitable, "-": not suitable, "(+)": limited suitability

3.5.3 Solid Waste Collection Situation

In recent years, collection of waste is carried out in order to reduce pollution on the island. The waste from the households, schools, offices, companies, markets, etc. would be collect directly with a handcart a garbage truck would then carry it to the disposal site. Currently, the workers only collect solid waste of households along main streets, markets and some other places that the truck can access. At all other places the waste is not collected creating the environmental problem for the whole area.

In general the solid waste collection on Phu Quoc Island is not adequate due to poor infrastructure, lack of investment and awareness of its people. Presently there are only 18 workers (13 who work in the Duong Dong area and 5 in An Thoi), four garbage trucks (with compactor) and seven handcarts that deal with the whole solid waste collection on Phu Quoc.

In general, waste collection and transportation runs smoothly, the involved teams have been able to accomplish the planned targets. The service has been recently expanded into different parts of the two towns Duong Dong and An Thoi, where most waste is to be found in Duong Dong and An Thoi market areas, particularly on the ocassion of traditional festivals and New Year's holidays.

Average daily volume of collected waste:	70 m^3
Annual volume of collected waste:	25,550 m^3
Collected street waste (sweepings):	260 m^3
Waste produced during New Year's holidays:	350 m^3
<u>Total for 2004:</u>	26,160 m^3, equivalent to 13,080 tons

To solve the above problem Phu Quoc's People Committee promulgated the instruction 04/2004/CT-UB on "*Intensifying the environmental protection and security on Phu Quoc*". This instruction has improved the environmental awareness of Phu Quoc's people.

Figure 3-21: Solid waste creating an environmental problem for sea beaches at Phu Quoc (IKrW, 11/2005)

With increasing population of the district, tourists and immigrants, the residence time of guests extends, the waste amount is increasing in coming years. In order to totally collect this waste, it needs investment in equipment as well as increasing manpower for managing agency e.g. Public Project Management Board of the district.

With increasing population, tourists and immigrants within this district as well as an extension of the guests' residence time, the waste amount is increasing in coming years, too. In order to collect all this waste investment in equipment is needed as well as increasing manpower for managing agency e.g. Public Project Management Board of the district.

3.5.4 Solid Waste Disposal

The household waste from the towns Duong Dong and An Thoi constitutes the major part of the island's total waste production. The daily waste generation in semi-urban areas has been estimated as 0.53 kg per capita. Taking into account the anticipated demographic growth, the annual quantity of household waste produced can be calculated to 15.5 million kg in 2005. In addition, approximately 1.5 million kg of food leftover and kitchen waste are produced annually by the major hotels and restaurants at the island's west coast.

At present, the waste collected is disposed off without prior treatment in an unmanaged disposal site located at An Thoi and Ong Lang (Duong Dong town). The solid waste dumped at these two sites is buried or burned (in the dry season).The current waste handling practice is leading to local environmental hazards such as rodents, smell and ground water pollutions. Furthermore, resulting uncontrolled emissions of methane (CH_4) have adverse environmental impacts on global climate change.

Figure 3-22: Un-managed disposal site on Phu Quoc (IKrW, December 2005)

According to the Master plan, two managed landfills (25 ha each) will be constructed nearby Cua Can and Ham Ninh. While waiting for the new landfills, the provincial government initiated plans to build a managed landfill in the island's north near the locality of *Xa Bai Thom* and some small disposal sites at Ganh Dau, Cua Duong, Duong To (1-2 ha each). The introduction of environmental sound waste handling practices is ranked high on the agenda of local as well as regional politicians, who want to promote eco tourism. Initiatives in the field of waste management will be boosted by the perceived urgent need to improve the island's environmental conditions.

3.5.5 Solid Waste Development

As the amount of household waste is strictly dependent on the socio-economic development of the studied area, the forecast of population growth has to be done for the whole estimated running time of the biogas plant. Since the exact date when the biogas plant will start effectively working is not yet known, the present feasibility study will take into consideration the period from 2005 to 2025 for estimating the amount of waste suitable for energy production on Phu Quoc Island.

The steady growth in number of inhabitants, as well as tourists and seasonal workers (due to the continuous development of Phu Quoc Island in the past years) indicate an important increase in the amount of waste to be disposed. A forecast of population growth is required for the next 20 years since the household waste produced by the inhabitants of the island constitutes the main feedstock for the biogas plant.

3.5.6 Waste Pickers

Waste recovery and recycling is a common manner in Vietnam and most of it is done by the poor and underprivileged class of people. The money gained from selling the recyclable parts collected from dumping sites is very little but for a lot people it is the only source of income.

There is not much known about the living and working conditions of waste pickers. A study conducted as part of the Canadian International Development Agency (CIDA) project on waste management (NGUYEN et al., 2004) identified the main problems faced by people picking waste from dump sites. The authors emphasized the health issues and the social needs of the people from the lowest level from the waste economy.

Figure 3-23: Waste pickers at a waste dumping site[11]

[11] WORLD BANK 2004

Apart from health and socio-economical aspects, the activity of waste picking needs to be taken in consideration when considering the household waste as a source for renewable energy. Most of the sold parts are plastics, paper or metals. Thus, their pre-collection can influence the general composition of substrates. Because very little is known about the quantities of recycled waste from dumping sites, only 50% of from paper, plastics and metals were considered available for further use.

3.6 Financing and Investment

3.6.1 Analysis of Local Conditions

For the assessment of the feasibility of a biogas plant the nature and size of the energy demand, the already existing supply of energy, the availability of biomass as a fuel resource as well as regulatory aspects have to be investigated. Furthermore, potential partners and all stakeholders influenced by the construction of the plant have to be identified.

3.6.1.1 First Overview about the Local Conditions

3.6.1.1.1 Supply and Demand of Energy Services

Regarding the regional supply and demand of energy services the conditions in different localities may be very distinct from each other. Depending upon the locality it is possible to build a plant in an off-grid area or to plan the production and disposal of grid-electricity. A captive or off-grid area is a situation when consumers are not connected to the electricity grid. In Europe or in North America this is a rare case and limited to isolate sites, where there are complicated and costly grid connection requirements. In developing countries this is very common in rural areas, where electricity companies have been unable to connect domestic, commercial, industrial or institutional consumers. In an off-grid area it is also possible to act as an independent power producer (IPP) offering energy to one or more users (e.g. industry or hotel) and selling overcapacities to a public or private power purchasing company as grid power.

Three cases may be distinct:

- Disposal of grid-electricity
- Acting as an IPP and selling surplus to the grid
- Energy production in an off-grid area

Depending upon the locality and the decision about the planned form of energy supply different questions have to be investigated while assessing the feasibility of the plant.

3.6.1.1.2 Biomass Availability

It is of major importance to check if there is full confidence on the availability of the primary fuel source needed for the production of energy in the long run.

3.6.1.1.3 Regulatory Aspects – Licenses, Permits, Approvals Needed

The relevance of regulatory aspects and the impact onto the realization of the project have to be assessed for the chosen locality. Any barriers resulting from the regulatory aspects that hamper or even impede the implementation of the plant should be found out in the early stages of project planning.

3.6.1.1.4 Identifying of Partners and Stakeholders

Partners to be involved in the project may be distinct between:

- partners who will have a financial stake in the project
- partners who are expected to provide immaterial contributions *(Immaterial contributions may be expertise, property or other services to the development, implementation or operation of the project)*
- partners who provide both financial as well as immaterial contribution (For instance, a strong local government unit could provide both equity contribution and interface with the local customers in matters such as payment collections)

Stakeholders are persons, groups or institutions with an interest (or “stake”) in what the project does. It means anyone who is directly or indirectly involved in it. Not only business partners also other people have a positive or negative interest in the project. So it is necessary to look which persons, groups or institutions are positively or negatively affected.

Table 3-16: Checklist to get an overview about the local conditions

Supply and Demand of Energy Services	Notes
<u>Disposal of grid-electricity</u> • How is the provision of energy in the region organised? • What is/are the power purchasing company/-ies? • Are they private or public companies? • Does a regional energy programme exist? (e.g. energy-mix) • Are there tariff subsidies, especially offered in this region? • What kinds of contracts are offered by the power purchasing company/-ies? (Duration, price et.) • How much of the power will be bought by the company? • Is the purchase lower than your plant capacity? • If the purchase by the company is lower than the plant capacity – is it useful to look for a single or more private user/s to which you may offer energy? • How and when will the company pay for the power? • How often (daily/weekly/monthly) will payments be made? • Is the company reliable in paying?	

Supply and Demand of Energy Services	Notes
Acting as an IPP and selling surplus to the grid • How is the provision of energy of the region organised? • Is their any provision of energy not covered by the grid? • What is/are the power purchasing company/-ies? • Are they private or public companies? • Does a regional energy programme exist? (e.g. energy-mix) • Are there tariff subsidies, especially offered in this region? • What kinds of contracts are offered by the power purchasing company/-ies? (Duration, price et.) • Are there users to whom you may sell electricity directly? • Who will buy and or use the power? (fabrics, hotels, private households etc.) • How much energy will these users buy? • How much of the power will be bought by the company? • Are there seasonal variations in the demand (caused by tourism or agricultural activities)? • Is the sum of purchases lower or higher than plant capacity? • How and when will the company/private users pay for the power? • Is the income stream of the buyers reliable? • How often (daily/weekly/monthly) will payments be made? • How much of the power will each buyer use? • What is the actual fuel price? • What is the willingness to pay for the energy? • Can your business set its own tariff or is the tariff to be set by a regulatory body? • Exist already distribution networks? • If not, how much has to be invested into the distribution network? • Is there any competition for the project? • Will grid electricity be available in future to all local users? • What are the incentives/ disincentives for users to purchase electricity from the project/from the grid? • What is the forecasted annual increase in electric energy consumption? • What is the expected development of peak load? • If you are working for the industry - will energy saving measures be introduced? • What is the willingness of industry to adopt biomass energy technology?	

Supply and Demand of Energy Services	Notes
Energy production in an off-grid area • How is the actual provision of energy? • Who are the potential users of energy? • What is their demand? • What will be their demand in the future? (e.g. increase of demand by higher living standards, television, refrigerator etc.) • Who will buy and or use the power? • How much energy will the users buy? • What is the actual fuel price? • What is the willingness to pay for the energy? • How much of the power will each buyer use? • Are there seasonal variations in the demand (caused by tourism or agricultural activities)? • Is the sum of purchases lower or higher than plant capacity? • How and when will the user pay for the power? • Is the income-stream of the consumers reliable? • How often (daily/weekly/monthly) will payments be made? • Can the business set its own tariff or is the tariff to be set by a regulatory body? • Exist already a distribution network and what are the constraints? • If not, how much has to be invested into the distribution network? • Is there any competition for the project? • Will grid electricity be available in future? • What are the incentives/ disincentives for users to purchase electricity from the project?	
Biomass Availability	**Notes**
• Are there enough fuel resources available to supply the energy? • Will this also be the case in the future? • How much will you pay for fuel resources? • How is the transport of the resources to the plant managed? • Is there already an infrastructure for substrate transport? • What are the costs for the logistics? • Are additional investments in the transport system necessary? • Are there any competing applications of the available substrates? • Will there be competing applications in the future, so that the price also may increase in future? • Is the supply of the substrate sustainable? • Are there seasonal differences in the supply (amount and price) of the fuel resource? • May this include a risk for the reliability of energy supply by the plant? • What could be potential back-up sources, if the main resource is not available for a certain time?	

Supply and Demand of Energy Services	Notes
Regulatory Aspects – Licenses, Permits, Approvals needed	**Notes**
• Permitting requirements for construction • Generation licensing requirements from the regulatory body • Environmental and pollution regulations • Regulations governing the appropriation of natural resources, including laws governing land, soil, ecology, etc. • Operation & Maintenance related laws • Tax codes, administrative codes	
Identifying of Potential Partners and Stakeholders	**Notes**
<u>Partners with financial stake in the project</u> • Project developer • Energy Performance Contractor (EPC) • Operation and Maintenance Contractor (O&M Contractor) • Financial Institutions • Insurance companies • Building, Construction and Engineering Companies • Lenders • Banks • Funds	
<u>Partners who might provide immaterial contribution</u> • Local government • Local administration • Central government and state level government, including; • the Ministry responsible for rural development, • the Ministry responsible for agriculture, • the Ministry responsible for environment and forests, • the Ministry responsible for energy or electricity, • the Ministry responsible for revenue and financing, or • the Ministry responsible for international affairs (if the project involves international financing or technical cooperation) • Nongovernmental organisations • NGOs dealing with environment and development, NGO labour organisations, farmers organisations, and trade organisations • Bilateral and multilateral organisations for example: • United Nations, World Bank, national aid agencies	

Supply and Demand of Energy Services	Notes
Potential customers • Public Power Company • Enterprises with large energy needs • Enterprises that could increase their profitability or productivity through improved energy services • Off-grid or remote enterprises • Enterprises setting up or expanding RE projects	
Potential biomass supplier • Enterprises with access to adequate supplies of inexpensive, reliable renewable resources • Households with access to adequate supplies of inexpensive, reliable renewable resources	
Local residents	

3.6.1.2 Choice of Project Partners

A profile of the necessary project partners should be developed in balance to the available financial and technical resources.

A profile for potential project partners should content:

- Required deliverable and performance
- Technical description of required deliverable and performance
- Required qualifications and experiences of partners, companies it is searched for
- Aimed forms of cooperation

Potential partners may be regional, national as well as international enterprises, in dependence to the national law about the kind and complexity of cooperation with foreign companies. (BEARINGPOINT (2003))

Where Asian banks look to while assessing the loan applicants (experiences from Asia after GONZALES (2001)):

- The developers managerial capability and competency
- The developers experience in managing an energy facility
- The developers family background
- The developers business associates
- The developers professional training
- The EPC contractors background and experience
- The O&M contractors experience
- The staff conducting the O&M
- The track record of the team working together
- Complementary or clashing skills among those who will be managing the project

Furthermore it is of importance to pay attention to the fact that a good and committed developer with limited experience is better than one who is not committed to the project. A committed developer or contractor deals with uncertainties more effectively.

If you intend to develop a CDM project it is useful to search for entities or individuals as potential additional equity investors who could provide access into CDM funds.

The participation of the community within the project could help to strengthen the project's responsibility for the community and environment. It may also help to overcome financial problems and problems appearing after the initial project phase. (GONZALES (2001))

Table 3-17: Checklist for the assessment of potential project partners[12]

Criterions Weight the criterions depending on the aim and intention of the project	Assessment 5=very good 4=good 3=medium 2=poor 1=very poor					Weighting 1=very important 2=important 3=not very important		Sum
Attributes, qualities	5	4	3	2	1	1-3	A*W	
Resources (Know-How, equipment)								
Technological competence								
Regular clientele								
Managerial capability								
Business segment								
Does the partner cover the business segment? (e.g. production, distribution, maintenance)								
Size of enterprise								
Has it the right size?								
Location								
Is the location of the registered office the right one? (e.g. region, infrastructure)								
Specific attributes								
Experiences in cooperation								
Engagement (investment of sufficient time, energy, personal into the cooperation?)								
Personal commitment								
Participation with equity								
Personal relationship								
Harmonizing of the corporate cultures of the partners								
Harmonizing of the business structures/ leadership								

[12] BEARINGPOINT 2003

3.6.1.3 Stakeholder Analysis and Observance of Project Acceptance

It has to be taken into account that there will always be a process of consents finding while developing a biomass project in an Asian country. Therefore it is of major importance to identify and establish linkages between partners and broad stakeholders who are affected by the project or activity. Only in this way you may ensure the establishment of awareness, acceptance and support in the future stages of the project implementation. (GONZALES (2001))

Who are Stakeholders?

Stakeholders are people, groups or institutions with an interest (or “stake”) in the project and its impacts. Meant is anyone who will be directly or indirectly involved in it. Included are not only business partner, but also all other people who have a positive or negative interest in the project.

It is necessary to investigate which persons, groups or institutions will be positively or negatively affected. The implementation of a biomass project implicates a lot of contracts and touches different businesses. It is necessary to think not only about the direct and immediate effects of the contracts (esp. financial effects). You should also pay attention to the indirect impacts and long-term effects. The indirect economic effects should be taken into account. Maybe someone is unfavourable affected. These people or institutions will probably hamper the project.

What is a Stakeholder Analysis?

It measures to enhance attractively and support to the project. It aims at getting insight into the following questions:

(a) Who is gaining and who is loosing from the project?

(b) What is the size of the stake for each stakeholder? (measuring in Dollar or Euro?)

Table 3-18: Checklist for stakeholder analysis and measures to enhance support from them[13]

Stakeholder	**Support and influence to the project, comments**	**Activities to enhance acceptance and support**
<u>Owner(s)/ Partners</u> - Project Developer - Operation and Maintenance Contractor (O&M Contractor) - Engineering, Procurement and Construction Contractor (EPC Contractor) - Biomass supplier - Energy Service Companies (ESCOs) - Power Purchaser - Lenders	The more owners and partners are involved the more problems may arise (caused by lacks of co-ordination and diverging interests). On the other hand more owners can contribute more resources to the project.	Pay attention to all legalities and agreements as well as to the structure of contracts. Major contracts e.g. include joint venture agreements, EPC contract, power purchase agreement, fuel supply contracts, agreements related to funding, agreements related to CDM and CER issuance.

[13] GRAF et.al. (2004); KARTHA, LARSON (2000); GONZALES (2001)

Stakeholder	Support and influence to the project, comments	Activities to enhance acceptance and support
Owners/ Partners	**Specific attributes, attitude to the project**	**Measures**
Financing Institutions and Insurance Companies	Many projects fall down because of problems related to project planning and getting construction permits. Lenders want the developer to analyse all project risks. They prefer projects that are backed by contractual partners who have a strong track record in their respective disciplines. Often lenders require an independent technical report prepared by a credible consultant.	Develop a plan how all risks will be apportioned. Ant all the terms of the contracts not to exceed the period over which the project debt will be repaid plus a reasonable margin to cover unforeseen events. Pay attention to the fact that lenders are also interested to see if they have recourse to the contracts.
Lenders, Financing Institutions and Insurance Companies	**Specific attributes, attitude to the project**	**Measures**
Equipment Supplier Engineering, Procurement and Construction Contractor (EPC Contractor)	The choice of the right technology is one of the major concerns in the development of a biomass project. RE-technology comes from different sources with varying degrees of efficiency and at various costs.	Pay attention to the reliability and capability of technology suppliers. It may be useful to tender the equipment supply to suppliers in the market. For this reason prepare a tender document with details about scope and specifications of the equipment supply. Send this to different EPC contractors to use them the document as help for submitting their bid.
Equipment Supplier	**Specific attributes, attitude to the project**	**Measures**
Biomass Supplier (e.g. landfills, but also enterprises or households with access to adequate supplies of inexpensive, reliable renewable resources)	It is usually not easy and very costly to switch the supplier, be-cause biomass involves high transport costs. The partner must be able to fulfil the contract in the long run. Any pre-existing use of biomass should be identified and satisfied through other means or integrated into the proposed bio-energy system. Existing use of biomass can be a main obstacle to the project in public opinion.	Pay attention to the sufficient fuel supply available for a period exceeding that of the financing. A proper designed agreement with the biomass supplier or suppliers is needed. The contract must ensure the continuous supply for a long time. It is important to look for what the biomass is used today.

Stakeholder	Support and influence to the project, comments	Activities to enhance acceptance and support
Biomass Supplier	**Specific attributes, attitude to the project**	**Measures**
Employees	If there is no long-run partnership between the developer or operator and the local people, it may happen that the project has no more support when the foreign partner is left and the project may close already after the initial project phase. In the long run it is necessary to find people who not just want a job but are motivated to care for the plant and maintain it. The employment conditions are of importance. Problems may be caused by a lack of acceptance of handling human faeces or animal manure.	Check if lacking knowledge will face a problem. Offer education, give information and train the people. Take care for motivating employment conditions and find people who not just want a job but are motivated to take care for the plant and maintain it.
Employees	**Specific attributes, attitude to the project**	**Measures**
Consumers (power purchasers may be local residents in an off-grid areas, a single private company, a public power purchase company)	It is important to create an energy system matching to the local conditions taking into account the consumer needs, the actual situation of the energy supply, net utilization, the energy framework conditions and regional energy programmes. The respect of local needs and knowledge and the participation of locals within the planning process secures acceptance and may also improve the payment morality.	Survey the local acceptance of the usage of renewable energy. Take into account that the change of the existing waste recovery system may cause acceptance problems. Respect the local knowledge, experiences, and abilities and let local people participate in the process of planning the plant.
Power Purchasers	**Specific attributes, attitude to the project**	**Measures**
Local government, administration and community	The respect of local needs and knowledge and the participation of locals within the planning process secures acceptance.	Pay attention to the sustainable development goals of the locality where you plan to implement the plant.

Stakeholder	Support and influence to the project, comments	Activities to enhance acceptance and support
	The project needs permits and licences from local authorities. Often there is some scope to interpret regulations and laws. So it may be necessary to find ways to convince the administration and probably to adapt the project.	Check if there are possibilities to integrate the project into the local economy system. Take care for the participation of the local officials within the planning process. Take the local attitudes and the already existing knowledge into account and pay attention to the spread of information, dissemination of knowledge, education and training.
Local Government and Administration, Community	**Specific attributes, attitude to the project**	**Measures**
Local Residents	These are the main stakeholders, which are indirectly affected. Often there is no direct contact with them but they are affected and they may protest. Issues may be environment, health, noise, bad smell, and increased traffic through biomass transport. Sometimes exist also religious taboos. Technologies that are not understood e.g. biogas are prone to blamed for any health problems in the community (even if there is no linkage at all). Sometimes unspecific fears exist e.g. with thermal treatment. Also barriers regarding the distribution of work exist. Possibly certain groups have some privileges that stem from belonging to a certain social, ethnic, age or sex group.	Survey the local acceptance of the usage of renewable energy. Take into account that the change of the existing waste recovery system may cause acceptance problems. Respect the local knowledge, experiences, and abilities and let local people participate in the process of planning the plant. Search for options to integrate the plant into the local economy, to create new job opportunities, and to bring additional income to the poor population. Pay fair prices to the fuel suppliers.
Local Residents .	**Specific attributes, attitude to the project**	**Measures**

Stakeholder	Support and influence to the project, comments	Activities to enhance acceptance and support
Other Stakeholders (E.g. State level government, including the Ministries responsible for rural development, agriculture, environment and forests, energy or electricity, revenue and financing or international affairs (if the project involves international financing or technical cooperation); Nongovernmental Organisations dealing with environment and development, Labour Organisations, Farmers and Trade Organisations, United Nations, World Bank, National Aid Agencies)	There are some more stakeholders that may be more or less involved. Their careful integration and involvement may be sometimes useful and beneficiary. The energy sector is a sector where the private and the public sector are working together. It has to be taken into account that their interests may be conflicting. The goals of private money stand in contrast with the goals of sustainable development. The evidence of sustainability of the project will be necessary if you apply for support from the state local government, financing institutions and nongovernmental organisations.	Assess the project regarding its sustainability effects. Pay attention not only to the environmental effects but also to the socioeconomic impacts caused by the project.
Other Stakeholders	**Specific attributes, attitude to the project**	**Measures**

3.6.2 Financing Models

There are different financing models possible for the implementation of biomass plants. Equity participation, on-balance sheet financing and leasing are conventional schemes of financing. In these forms the financing goes directly to the owner of the plant. The project finance, Public Private Partnership model (PPP) and the financing with the help of the Clean Development Mechanism (CDM) are more innovative finance models where the financing goes to the project company respectively to the project developer or to the host country of the CDM project.

These different financing schemes vary in their terms of the financing structure (debt/equity-ratio), the maturity of loan offered to them, the extent of their up-front costs, the investment of time for necessary legal documentation and the distribution of risks between the partners involved. All models have advantages as well as disadvantages.

3.6.2.1 Conventional Financing

Equity participation, on-balance sheet financing and leasing can be seen as traditional financing models. While within the equity financing the company uses its own internal funds to finance the investment, on-balance sheet financing means that borrowings from a bank are made. These are reflected on the balance sheet of the owner of the plant. The approach of leasing helps to overcome the high up-front costs of purchasing the technology. But at the end the additional costs, which are assessed by leasing companies, result in higher financial costs than in other financing models.

There are two ways open if you have taken the decision for a conventional financing model. You may invest and develop the project alone or you make a joint venture with at least two partners.

If you choose to invest and develop the project alone you should have a stable business base and a strong financial standing. The advantage is that you become then the sole owner of the business. If the investment is made within a joint venture the share of the facility ownership will be determined in proportion to the amount of investment put in by the different partners.

3.6.2.2 On-Balance Sheet Financing

The on-balance sheet financing model is the simplest form of raising funds. The project sponsor respectively the owner of the biomass plant takes out the loan to finance the project. The loan is reflected on the balance sheet of the sponsor.

In Figure 3-24 an example is shown for a biomass facility financed through on-balance sheet financing. The plant is owned by and integrated to the landfill. It sells electricity to the grid. Investments are usually financed by borrowings from local commercial banks at the rate of 50-100 % of the investment costs. The difference is financed from the plants owner balance sheet or through internal cash generation.

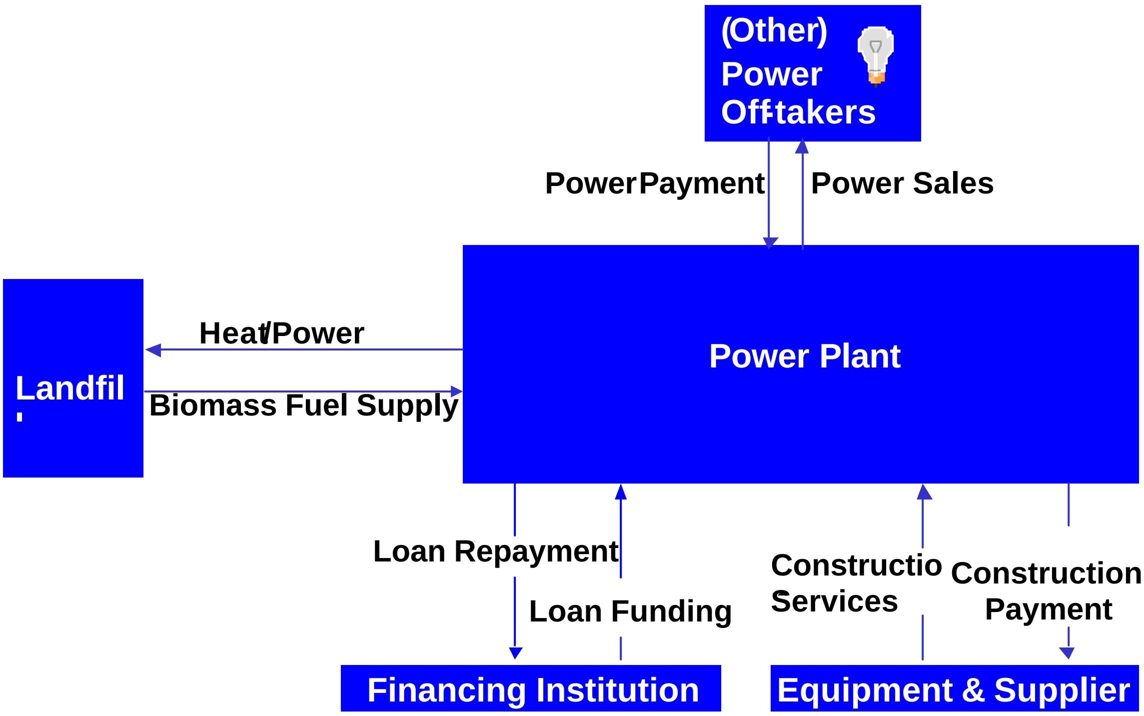


Figure 3-24: On-Balance Sheet Financing

One advantage is that this type of financing can be arranged quickly. Furthermore, only simple documentation and security arrangements are required. On the other hand the risks are mainly carried by the sponsors, which is a major disadvantage. The loan increases the debt burden on the balance sheet of the sponsors. Therefore it may be used only by strong corporate sponsors. The repayment periods are not long (normally < 10 years).

3.6.2.3 Project Finance Model

The introduction of subsidies for renewable energy is supporting the shift from the traditional corporate finance to the more innovative finance or project finance. In this model a special purpose company is funded only for the implementation of the plant. The project company takes out the loan to finance the project. The source of debt service (loan + interest) is primarily the cash flow from the project.

3.6.2.4 Public Private Partnership

The Public Private Partnership structure is one kind of models of project financing. The project company borrows from the lending institutions in order to finance the construction of the facility. The loans are repaid from tariffs paid by the government under the off take agreement during the life of the concession. At the end of the concession period the facility is usually transferred back to the government.

3.6.2.5 Financing with the Help of CERs/CDM

The CDM is a mechanism to promote investments in greenhouse gas (GHG) emissions reduction projects in developing countries, which would not get into implementation otherwise. The emission reductions generated from projects can be sold and so provide additional cash flows into the project. In this way emission reduction sales may increase the financial performance of the project[14].

3.6.3 Financial Sources for Renewable Energy Projects

3.6.3.1 Financing Sources

For small-scale biomass projects the lack of financial resources is one of the major obstacles. It is necessary to search for capital to extend the equity provided by the owner of the project, and sometimes even the equity has to be sought from other potential investors. While searching for capital the following sources of financing may be addressed:

- Overseas development assistance (ODA): Multilateral Financing, Bilateral Financing
- Private Financial Sources: Private investment banks, companies active in the field of privatization, companies involved in PPP projects, foreign direct investment (FDI) companies
- Other relevant projects funding opportunities: CDM

[14] HENZLER, M.; JANISCHEWSKI, J. (2000); TODOC, L.J. et.al. (2003); FICHTNER, RENTZ (2003); CARLOS (2004); GONZALES (2001))

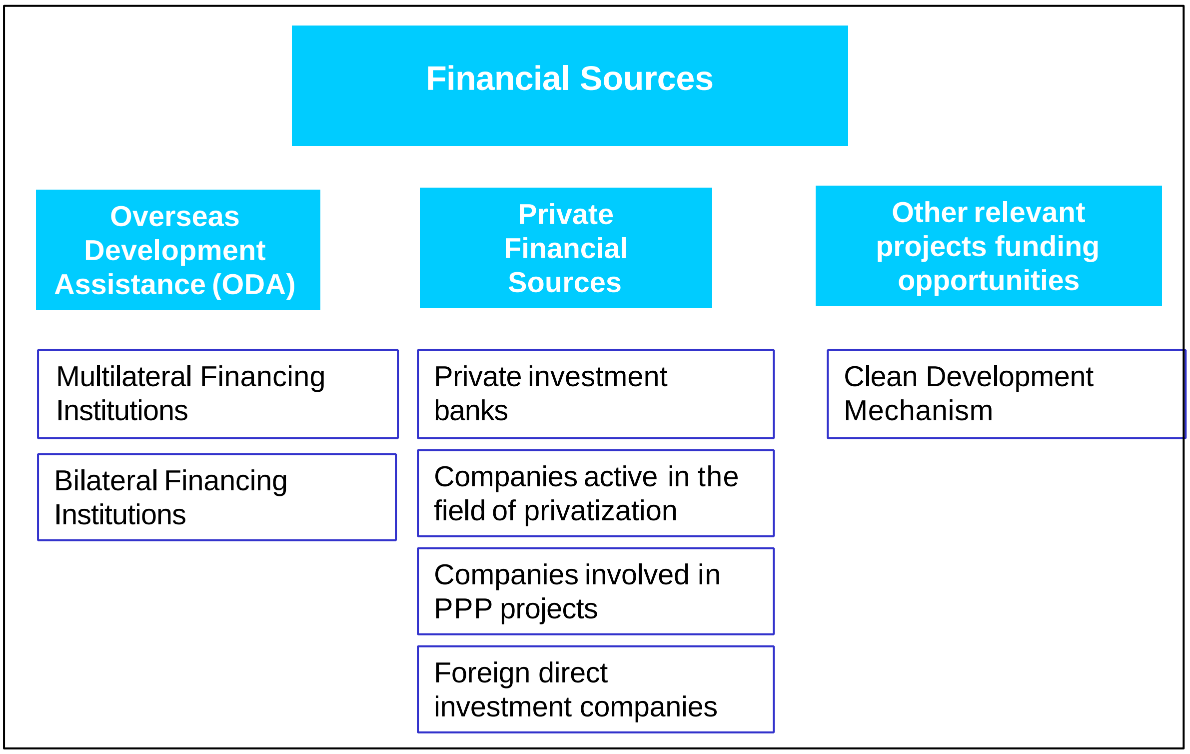


Figure 3-25: Financial sources for biomass projects

3.6.3.1.1 Overseas Development Assistance (ODA)

Multilateral Financing Institutions

Multilateral Institutions, such as the Asian Development Bank and the World Bank, only provide a small portion of the financing required for energy projects. But they are important for development countries for the following reasons:

- Their participation in projects improves the creditworthiness of projects in the eyes of private investors.
- Their administrative and regulatory procedures are signed by transparency.
- They often provide financial risk management products, such as partial bond guarantees to share project risks with bond issuers (APEC (2003)).

Multilateral Institutions may provide funding to member countries or to the private sector. Furthermore, they may offer project financing (targeted project credits). Because national or local banks often are not familiar or willing to enter new markets, this approach helps them to develop knowledge and expertise for assessing similar projects in the future. Project credits offered by Multilateral Agencies help to overcome the financial barrier of “no track record” new technologies are often faced with.

Bilateral Financing Institutions

Bilateral agencies are government-affiliated organizations, such as the Export-Import Bank of Thailand and Export-Import Credit Agencies of the Organization for Economic Cooperation and Development (OECD) member countries. Loans offered by export-import banks often have a longer maturity than commercial bank loans. As energy projects often are characterised by a long lifetime this is a major advantage for them. (APEC (2003))

3.6.3.1.2 Private Financial Sources

Private Investment Banks

Commercial banks are the most popular source of financing. The types of commercial bank loans vary depending on its use, e.g. there are construction loans, mortgage loans or working capital loans [LIMTHONGSAKUL et.al. (2002)]

Companies Active in the Field of Privatisation

There are more and more companies active in the field of privatization in the Asian energy sector. The increasing supply of private developers in the power sector in South East Asian countries includes equipment suppliers, consulting companies, construction companies, fuel suppliers and Independent Power Producers (IPP) (an IPP is a private entity that operates a generation facility and sells power to electric utilities for resale to retail customers).

Companies Involved in PPP Projects

Within a Public-Private Partnership the public sector and a private sector company come together to provide a facility-based environmental service. Public participation can contribute local knowledge and build a stronger commitment to solutions. Consultation with private investors can help the public sector to identify more cost-effective approaches.

Foreign Direct Investment (FDI) Companies

A foreign direct investment company may be a European company that takes a direct investment in an Asian country. A foreign direct investment implies a long-term relationship between the direct investor from the foreign country and the enterprise in the host country of the project.

3.6.3.1.3 The Clean Development Mechanism

The sales of CERs can secure additional income streams of projects. If there is a commitment for the purchase of CERs a stable profitability may be secured.

3.6.3.2 Financial Instruments

While searching for capital or for support to a biomass project you may take advantage of different financial instruments or products:

Commercial Bank Loans

Commercial bank loans are more available than bond or equity financing. The maturity is in average five or six years and shorter than this of bonds. The interest rates are higher than those on bonds.[15]

[15] APEC (2003)

Loans from Multilateral Institutions or Bilateral Agencies

The maturity of such loans is in average ten years and therefore longer than this of commercial bank loans. But their availability is lower and often there are restrictive purchase provisions.[16]

Bond Financing

The maturities of bonds range from five to ten years. The interest rates on them are lower than these on commercial bank loans. The approval process acquired is long and the expenses of issuing bonds may be 3 percent of the amount issued. (APEC (2003)). The development of regional bond markets in Asia became a policy priority for a number of governments in recent years.[17]

Equity Financing

Stockholder have a higher risk than bondholders. That's why equity financing efforts higher costs than bond financing. Quasi-equity means products, which are a combination of loan and equity. This makes it possible to find flexible solutions to meet the special requirements of each project.[18]

Grants

One of the principal barriers identified for RE are high project development costs in relation to the investment ratio. A number of multilateral, bilateral and national sources have established funds or programmes to help RE projects/ developers to overcome high development costs. Provided are specifically technical assistance grants and grants to finance feasibility studies.

Intermediary Financing

A financial intermediary borrows money for on-lending. As many countries don't have a developed capital market that provides the required funding from domestic sources local financial institutions often have to turn to external financing sources. In this way local commercial banks may act as financial intermediaries between international financing institutions and investors in renewable energy.

Financial Risk Management Products

To help companies in managing and controlling the risk included by energy projects financial institutions offer financial risk management products, such as various types of insurances, to their clients.

Advisory Service

Many multilateral and bilateral financing institutions provide advice and technical assistance to private businesses and governments in developing countries. They may also help companies in developing countries to tap into international capital markets. Furthermore they may give expertise on sustainability.

[16] APEC (2003)

[17] Reserve Bank of Australia (2003)

[18] APEC (2003)

Table 3-19: Overview about financing institutions offering support to foreign investments in renewable energy in ASEAN countries

Overview about Financing Institutions Offering Support to Foreign Investments in Renewable Energy in ASEAN Countries			
	Host countries eligible for financing	**Recipients**	**Financing products**
EIB, European Investment Bank financing under the ALA III mandate	*Brunei, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam*	*Project developers. Investors, Lenders, SMEs, Financial Intermediaries, Governments, Private companies, Public sector*	*Financial risk management products,* *Loans, Intermediary finance*
International Finance Corporation (IFC)	*Brunei, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam*	*Private Sector*	*Loans, Equity-Finance, Financial risk management products, Intermediary finance, Advisory services*
IFU, the Danish International Investment Funds	*Developing countries*	*Danish trade and industry, SMEs*	*Equity capital, Loans*
The Finnish International Fund, Finnfund	*Developing and transition countries*	*Finnish companies and project developers, Ventures that cooperate with Finnish partners*	*Equity capital, Loans, Financial Risk management products*
Mekong Enterprise Fund	*Vietnam, Laos, Cambodia*	*Private companies in Vietnam, Laos and Cambodia*	*Equity, Advisory services*
Swedish International Development Cooperation Agency (SIDA)	*Cambodia, Philippines, Indonesia, Laos, Thailand, Vietnam*	*Swedish private companies, SMEs, Public sector, NGOs and research institutions*	*Credit and investment support*
The Netherlands Development Finance Company (FMO)	*Developing countries*	*Private companies, Financial institutions, Project developers*	*Loans, Financial risk management products, Equity capital*

The Belgian Investment Company for Developing Countries, (BIO)	*Asia*	*SMEs, Financial intermediaries, Financial institutions*	*Loans, Intermediary finance, Grants, Advisory services*
	Host countries eligible for financing	**Recipients**	**Financing products**
KfW/ KfW IPEX-Bank - KfW/ERP Export Fund – CIRR Export Financing Programme for developing countries	*Indonesia, Cambodia, Laos, Philippines, Vietnam*	*German project developers, Private companies*	*Loans, Equity, Intermediary finance, Financial risk management products, Advisory services*
DEG, German Investment and Development Company	*Developing and transition countries*	*Project developers and private companies form Western Europe involved in PPP-programmes*	*Loans, Equity, Financial Risk management products, Advisory services*
Swedfund	*Southeast Asia*	*Swedish private companies*	*Equity, Loans, Financial risk management products, Part-financing of leasing agreements*
The Nordic Investment Bank (NIB)	*Developing and transition countries*	*Private companies, SMEs, Governments, Public sector from Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, Norway or Sweden, Development banks*	*Loans, Financial risk management products, Intermediary financing*
NORFUND is a Norwegian development financial institution (DFI), SN Power Invest	*Developing countries*	*Private companies*	*Equity, Loans, Advisory services*
SBI/BMI - Société Belge d'Investissement International, Belgium	*Vietnam*	*Belgian private companies*	*Equity and quasi-equity*
MIGA, the Multilateral Investment Guarantee Agency	*Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam*	*Companies and project developers from Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, Switzerland, United Kingdom*	*Financial risk management products*

GEF, Global Environment Facility	*Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam*	*SMEs, Governments, communities, local people, NGOs, CBOs, Project developers*	*Grants, Advisory services*
	Host countries eligible for financing	Recipients	Financing products
World Bank	*East Asia and Pacific region*	*Governments, Project Developers*	*Loans, Grants, Advisory services, Procurements*
The Asian Development Bank (ADB)	*Indonesia, Malaysia, Philippines, Singapore*	*Private companies*	*Equity, Loans, Grants, Financial risk management products, Promoting of CDM projects*
The Global Village Energy Partnership (GVEP)	*Cambodia, Indonesia, Laos, Philippines, Vietnam*	*Governments, Public and private organizations, Multilateral institutions, Consumers*	*Advisory services, Intermediary Finance*
Asia Pro Eco Programme	*Cambodia, Indonesia, Laos, Malaysia, Philippines, Thailand, Vietnam*	*European and Asian public or non profit organisations*	*Grants, Advisory services*
Asia-Invest II Programme,	*Indonesia, Cambodia, Laos, Malaysia, Philippines, Thailand, Vietnam*	*European and Asian public or non profit organisations*	*Grants, Advisory services*
Public-Private Infrastructure Advisory Facility (PPIAF, World Bank)	*Development and transition countries*	*Governments, public and private companies*	*Grants, Advisory services*
Public-Private Partnerships for the Urban Environment (PPPUE, UNDP)	*Development and transition countries*	*Governments, public and private companies*	*Grants, Advisory services*
German Agency for Technical Co-operation (GTZ)	*Cambodia, Indonesia, Laos, Malaysia, Philippines, Thailand, Vietnam*	*Governments, public and private institutions*	*Grants, Advisory services*

3.6.3.3 Developing a Financing Package

The goals of project sponsors in terms of the structure of financing options are:

- Maximization of debt maturity
- Minimization of costs of debt
- Minimization of covenant restrictions
- Maximization of flexibility of terms on post-closing
- Minimization of time to achieve closing (APEC (2003)).

The project sponsor has to balance these key objectives against the advantages and disadvantages of various financing options. Generally the equity portion is between 20 and 40 percent while the debt portion is between 60 and 80 percent. A higher equity share represents higher commitment by the project sponsors. This makes the project less risky to lenders.

Because of high up-front costs and relatively long payback periods for renewable energy systems, longer-term financing (10 to 15 years) is essential to a project's viability (ICRA (2005 b)). To secure long-term financing for a power project it is useful to combine different financial instruments. Combinations provide flexibility and can mitigate investment risks because of the different terms and asset coverage associated with each instrument. (APEC (1998))

Small-scale project developers normally don't have expertise in the financial packaging of projects. That's why it is very useful to them to take the help of a financial advisor (GONZALES (2001)). A financial advisor may help you:

- To find out the right debt-equity ratio
- To design the right finance mix
- To arrange additional financial contributions if necessary [APEC (2003)][19].

3.6.3.4 Experiences from Asian Countries

Renewable energy projects are mostly small and medium sized enterprises (SMEs). And so they face also the same problems as SMEs do. The lack of access to finance is the major problem of them. The reasons are:

- Their high vulnerability to changing market conditions,
- High failure rates compared to large enterprises,
- Banks prefer large corporate borrowers or public sector entities, little experience in accounting and other financial documentation, therefore, banks have difficulties to assess their creditworthiness,
- High administrative costs in contrast to small loans[20].

As for small-scale projects the lack of financial resources is one of the major obstacles it is necessary to search for capital to extend the equity provided by the owner of the project. Sometimes even the equity has to be sought from other potential investors. [GONZALES (2001)]

[19] GONZALES (2001)

[20] HENZLER, M.; JANISCHEWSKI, J. (2000)

Commercial banks in South East Asian countries generally have a low awareness of biomass technologies. There is a high-risk perception of privately initiated renewable projects with high and long term financing (10-15 years). This is the reason why loans from commercial local banks often are not available for non-traditional power projects (ICRA (2005 b)). For this reason it is useful to pay attention to experiences made by investors in ASEAN countries and to take them into account while searching for lenders and equity partners.

When banks provide loans to single-purpose companies they prefer those, which may show that their energy sales are guaranteed by power purchase agreements. Furthermore it is useful to the owner of a biomass facility to search for partners who have a proven track record in investing or in developing similar plants. While applying for a loan it will be of major advantage if the owner of the facility has partners with experiences in developing power plants (GONZALES (2001)).

While assessing loan applicants Asian Banks look to the following criteria:

- The developers managerial capability and competency
- The developers experience in managing an energy facility
- The developers family background
- The developers business associates
- The developers professional training
- The EPC contractors background and experience
- The O&M contractors experience
- The staff conducting the O&M
- The track record of the team working together

Complementary or clashing skills among those who will be managing the project [GONZALES (2001)].

If the owner of the plant is not the fuel supplier itself financial institutions prefer if the fuel suppliers take equity stages in the project. If this is not possible banks will be interested in long-term fuel supply contracts[21]. Because banks prefer a low project risk it will always be of advantage to reduce the risk at all instead of only allocating it to the partners.

Some steps that could make projects more attractive to lenders are the following measures:

- Preparation of a financial plan which reflects the credit structure of the project
- Use of the service of a financial advisor
- Preparation a Project Information Memorandum (PIM) which reflects the due diligence efforts of the project developers
- Search for equity partners who have a proven track record of investing in and/ or developing similar types of facilities
- Reduction of complexity to lower costs
- Reduction of risk instead of allocating it
- Creation of alliances with others to develop portfolios including more projects
- Work along with governments to reduce the total risk on a project during its construction and its operational life [22]

[21] TODOC et.al. (2003)

3.6.4 How to Overcome Risks

As in biomass projects many partners may be involved many problems may arise caused by lacks of co-ordination and by diverging interests. In Figure 3-26 all stakeholders with a financial interest in a PPP project are shown. It is of major importance to pay attention to all legalities and agreements and to the structure of contracts with the involved partners. Major contracts e.g. include joint venture agreements, the EPC contract, power purchase agreement, fuel supply contracts, agreements related to funding and if there is participation in the CDM also agreements related to CDM and CER issuance.

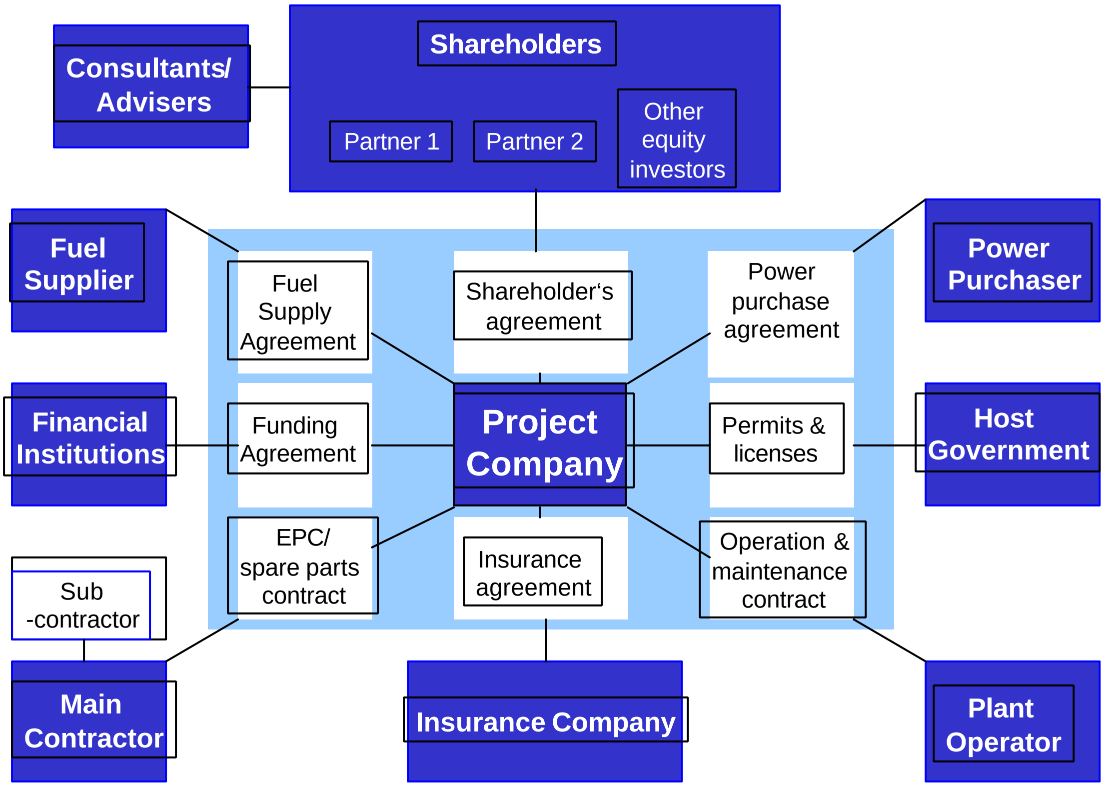


Figure 3-26: Stakeholders with a financial interest in a project[23]

It is important that the developer analyses all project risks and develops a plan how all risks will be apportioned. According to the project risks and its allocation lenders often require an independent technical report prepared by a credible consultant.

Contracts allow transferring the risks from the project developer to the partners who are in the best position to manage them. But the preparation of contracts also requires a high complexity. The resources, which are necessary for their preparation must be taken into account, while making the time plan and calculating the project costs. There are different measures to mitigate risks. Mitigation measures and possibilities to allocate risks are given in Table 3-20 .

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[22] GONZALES (2001), ICRA (2005 b), APEC (2003)

[23] CARLOS (2004)

Table 3-20: Risk allocation and mitigation matrix[24]

Risk	Allocation							Mitigation
	Government	Sponsors	Project company	Third party contractor/supplier	Project lenders	Insurers	Performance & other bond banks or insurers	
Fuel								**Fuel supply availability study, long term fuel supply contract,** **storage of rice husk during lean season**
Supply availability			**X**	**X**				
Price			**X**	**X**				
Financial/legal								**PPA from utility including provision for foreign exchange and fuel price fluctuation,** **equity from sponsors,** **fixed rate loans,**
Inflation	**?**	**?**	**X**		**X**			
Interest rate	**?**	**?**	**X**		**X**			
Foreign currency exchange rate	**?**	**?**	**X**		**X**			
Ownership of assets			**X**					

[24] GONZALES (2001)

Security structure					**X**			**hedging mechanisms such as interest swaps,** **joint venture agreement**
Insolvency of company		**X**			**X**			
Breach of financing documents		**X**			**X**			
Enforceability of security					**X**			
Operation								
Company default		**X**						
Termination of O & M contract by company			**X**					
Environmental damage ongoing			**X**			**X**		
Force major event	**X**		**X**			**X**		
Change in law			**X**	**x**				
Labour			**X**					
Market and revenue								**PPA from utility** **Established power purchase scheme** **Long-term purchase / distribution contract for by-products**
Insufficient income		**?**	**X**		**?**			
Off-taker default			**X**	**X**	**?**		**X**	
Insufficient demand		**?**	**X**		**?**			

3.7 Stakeholders

As mentioned in Chapter 3.6.1.3, stakeholders are people, groups or institutions with an interest (or “stake”) in the project and its impacts. Anyone who will be directly or indirectly involved in it belongs to this category - not only business partners are included, but also all other people who have a positive or negative interest in the project. According to the generation of renewable energy on Phu Quoc, there are three main categories of stakeholders:

3.7.1 Governmental Institutions

Representatives of the governments concerned are interested in a sustainable cooperation between countries of the EU and ASEAN member countries by transfer and exchange of knowledge and know-how in the field of renewable energy and technical solutions for ASEAN countries.

3.7.1.1 Europe

The European Union aims to promote the *ASEAN Plan of Action for Energy cooperation 1999-2004* by supporting the implementation and installation of a renewable energy facility on Phu Quoc. This plan aims to improve the current energy situation (e.g. on Phu Quoc); by providing a EU-co-funded feasibility study, the current efforts of the local decision-makers should be supported. Furthermore, the protection of the environment at a global level means that the anyone concerned with renewable energy can be seen as a stakeholder.

3.7.1.2 Vietnam

The national, regional and local governments responsible for the development of Phu Quoc island are the most important decision makers with in the project. All levels of the involved governmental authorities and institutions are proponents of the project’s objectives and further development.

There is a general agreement to support the political aim of a sustainable development of Phu Quoc island by the promotion of socially and environmental sound, safe, reliable and cost-efficient solutions for renewable energy facilities. According to the Prime Minister’s decision to support eco-tourism on Phu Quoc, especially the authorities of local and regional levels aim to protect the local environment by reducing all kinds of pollutions, including those related to the generation of conventional energy.

In order to indicate interest, the following authorities and governmental institutions sent representatives to the workshop carried out on 5th December 2005 in Duong Dong / Phu Quoc.

Table 3-21: List of workshop participants

Authorities and Governmental Institutions:	**From:**
Office of the Government Ministry of Natural Resources & Environment Electricity of Vietnam Ministry of Sience & Technology Ministry of Industry	Hanoi
Power Company 2 Department of Natural Resources & Environment Ministry of Investment & Planning	Ho Chi Minh City
Office for Foreign Affairs Department of Sience & Technology Department of Natural Resources & Environment Kien Giang College of Community Kien Giang Electric Company Kien Giang People Committee Department of Industry	Kien Giang
District Communist Party Phu Quoc District People Committee Commercial and Tourist Office Office of Industry Phu Quoc Television Station	Phu Quoc

The purpose of this workshop was to inform Vietnamese decision-makers, planners and managers about the options to generate renewable energy from organic waste and biomass. Furthermore, it should have been a opportunity to facilitate an exchange between European and Vietnamese know-how and best practices. The representatives of these stakeholders took part in the discussions and agreed to support the further development of this project.

The most valuable paper for the implementation of further developments is a “Letter of Intent”[25] sent by the People Committee of Kien Giang underlining the intent to clarify the legal conditions and to get financing for a power plant construction.

25 People Committee of Kien Giang Province (Nr. 654/UBND-KTCN) dated 13th October 2006

3.7.2 Business

From the EU-business' point of view, the stakeholders aim to promote European products, such as plants to produce renewable energy as well as know-how, methodologies, tools and services for the export into the ASEAN market.

European companies, such as *BEKON Energy Technologies GmbH & Co. KG* and *ATZ Entwicklungszentrum* supported this feasibility study by providing technology descriptions and figures. The consortium products of these companies have been found adequate regarding to the invented pre-conditions on Phu Quoc.

Since the field of renewable energy is relatively unknown in Vietnam, this business is still undeveloped. Furthermore, energy generation by *Energy of Vietnam* (EVN), respectively *Power Company II* (PC 2) is state owned and thus, these stakeholders are already included in the previous chapter 3.7.1 above. Nevertheless, the growing market of renewable energies is favourable for Vietnam's rural areas and increasing electricity demand in general, this will cause a growing number of interested stakeholders in the future.

One of the stakeholders is the *Southern Foreign Investment Center,* who also joined the workshop in Duong Dong, is very interested in renewable energy projects.

3.7.3 Residents

Protecting the environment at a local level is a rather minor aspect for the population on Phu Quoc. The environmental awareness is still undeveloped as environmental problems were just rising up with increasing industrialization and living standard during the last decades.

People here take much more attention to the improvement of an secure electricity supply, permanent employment and additional sub-businesses, i.e. suppliers of construction and maintenance materials, transportation, etc.

Nevertheless, it becomes more and more popular to protect the environment and support the improvement of living standards. The authorities welcome any improvements of waste management to keep the island green and clean – not only to attract tourists.

However, the generation of electricity from renewable energy sources will reduce various pollutions (air and noise pollution of conventional facilities, uncontrolled waste disposal and its resulting smell, water and soil pollution). This will improve residential conditions on Phu Quoc.

4 Feasibility of Options for Renewable Energy Assessed

4.1 Options Regarding Location A and B

4.1.1 Assessment Option A: Landfill near Cao Can

Cua Can is a quiet village of 38.74 km² on Phu Quoc island. It is situated on the Northwest coast of the island and about 10 km North of the islands capital Duong Dong (Figure 4-1). It is surrounded by bush land.

Figure 4-1: Masterplan for Cua Can and its surrounding area

The population is about 2829 living in rather small houses along the river and along the road.[26]

Cua Can is quite well connected with the capital via a sandy road along the west coast. Transportation of large goods might be possible by boat but also dfficult to unload caused by insufficient technical facilities (e.g. cranes). The village has just a small port for fishing boats. Fish processing workshops are placed nearby the river.

Due to the existing disposal place situated approx. 3 km south of the village, an early stage of waste management is already present in the area (see Figure 4-2).

[26] Department of Construction, Phu Quoc 2004

Figure 4-2: Simple disposal site nearby Cua Can (IKrW, December 2005)

Nowadays, the island's electricity grid ends in Cua Can coming from Phu Quoc power station in Cua Duong (Figure 4-3). The landfill site could be connected with the grid more-or-less easily depending on the final location.

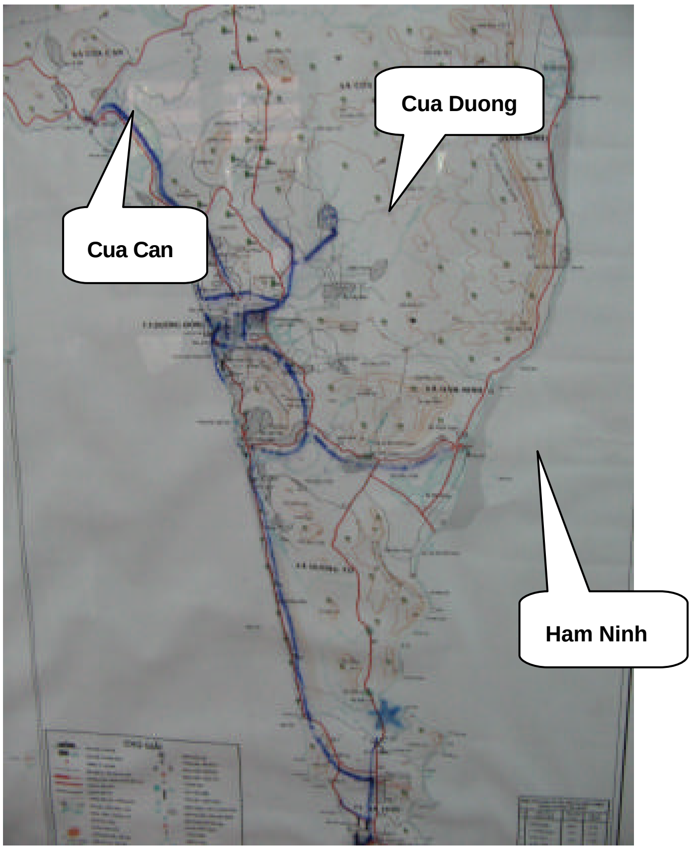


Figure 4-3: Electricity grid on Phu Quoc as per 2004 (blue lines)

The villages further north are not connected and receive electricity from small generators just periodically. Thus, the surrounding of Cua Can would be a suitable location to erect a power plant in order to provide electricity to those villages in case of a northward grid extension.

These strategic aspects have been underlined by Phu Quoc's actual Masterplan meeting the Prime Minister's decision decision No. 178/2004/QD-TTg. It plans to open a new landfill in Cua Can's surrounding. Even though no certain location for the landfill has been defined so far, it would be a suitable place to erect a power station utilising waste for the generation of energy.

4.1.2 Assessment Option B: Landfill near Ham Ninh

Ham Ninh is a idyllic village of 81.45 km² on Phu Quoc island. It is situated on the East coast of the island and about 10 km Southeast of the islands capital Duong Dong (Figure 4-4).

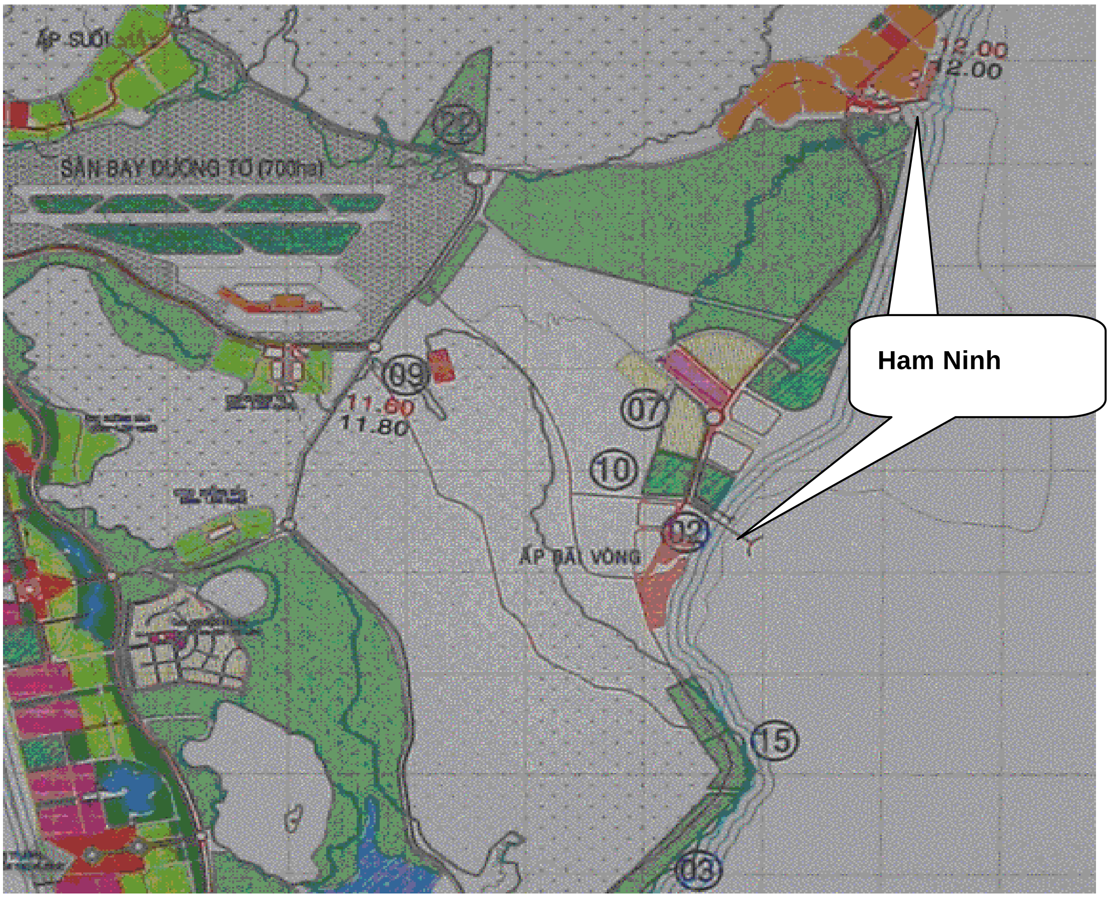


Figure 4-4: Masterplan for Ham Ninh and its surrounding area

The population is about 4867 living in rather small houses along the river and along the road.[27]

The village is well connected with the capital via an asphalt road. Connections to a potential landfill property would be possible for transportation of large goods (construction materials) by lorries, e.g. from ports of Duong Dong or An Thoi. The port of Ham Ninh is unsuitable for handling of goods as shown in Figure 4-5.

[27] Phu Quoc 2004

Figure 4-5: Port of Ham Ninh (IKrW, December 2005)

Nowadays, the island's electricity grid ends in Ham Ninh Centre coming from Phu Quoc power station in Cua Duong (see Figure 4-3). The landfill site could be connected with the grid more-or-less easily depending on the final location.

All the households along the east coast are still without electricity supply. Just some of them have small private generators and partly provide energy to their neighbours. Thus, the region around Ham Ninh would be a suitable location to erect a power plant. On the one hand, it could provide electricity to households along the coastline in case of grid extension and on the other hand, it would ensure the energy supply for hotels and services of the tourism sector which extends in the southern part of the island.

These strategic aspects have been underlined by Phu Quoc's actual Masterplan meeting the Prime Minister's decision No. 178/2004/QD-TTg. It plans to open a new landfill nearby Ham Ninh. Even though no specific location has been defined for the landfill so far, it would be a suitable place to erect a power station utilising waste for the generation of energy.

4.1.3 Comparison of Options A and B

Comparing both options relating to a suitable location of a power plant the following Table 4-1 serves as an overview and might help to decide:

Table 4-1: Comparison between the two locational options assessed

Features/Aspects	Cua Can	Ham Ninh
Property available	yes	yes
Property characteristics	bush land	bush land
Infrastructure / Connection		
• traffic (road)	• existing (sandy) or feasible	• existing (asphalt) or feasible
• electricity	• existing or feasible	• existing or feasible
• water	• not existing but feasible	• not existing but feasible
• waste water	• not existing and not feasible	• not existing and not feasible
Catchment area	mainly Duong Dong and villages in the north and centre	mainly Duong Dong, An Thoi and villages in the south and east
Interfaces with existing power plant	none; completely new construction and equipment	none; completely new construction and equipment
Waste collection	to be implemented in northern villages	to be implemented at the eastcoast

As seen in Table 4-1 there are no essential criteria for or against one of these locations. But as a matter of fact, it would be more ensured to run the plant effectively when it is situated in Ham Ninh as the waste of both towns, Duong Dong (24,100 inhabitants) and An Thoi (17,900 inhabitants) could be used for energy generation. It might be the same way from Duong Dong but it is recommended, not to transfer the southern waste of An Thoi to a northern landfill. However, Cua Can would be a suitable alternative in case of exceeding the capacities or any unforeseen interruption of processing.

4.1.4 Recommendation for Location

Regarding the amount of waste to be utilised for renewable energy generation and reduction of transportation costs, the consortium recommends the landfill located nearby Ham Ninh. Located between the two cities of the island, the distance of waste transportation to a treatment plant can be minimised. According to the masterplan for the development of Phu Quoc Island and its anticipated new airport, the provision of infrastructure will be improved and can be used for construction and operating of a waste treatment plant nearby Ham Ninh.

4.2 Option 1: Biogas Plant

This feasibility study reviews a dry fermentation called "*BEKON dry fermentation process*" that was investigated, developed and patented by the German company *BEKON Energy Technology GmbH & Co. KG*.

4.2.1 Process Design and Technical Assessment

A dry fermentation technology was found potentially suitable for the given framework conditions and had been assessed. Figure 4-6 shows the simplified flow chart of a dry fermentation process.

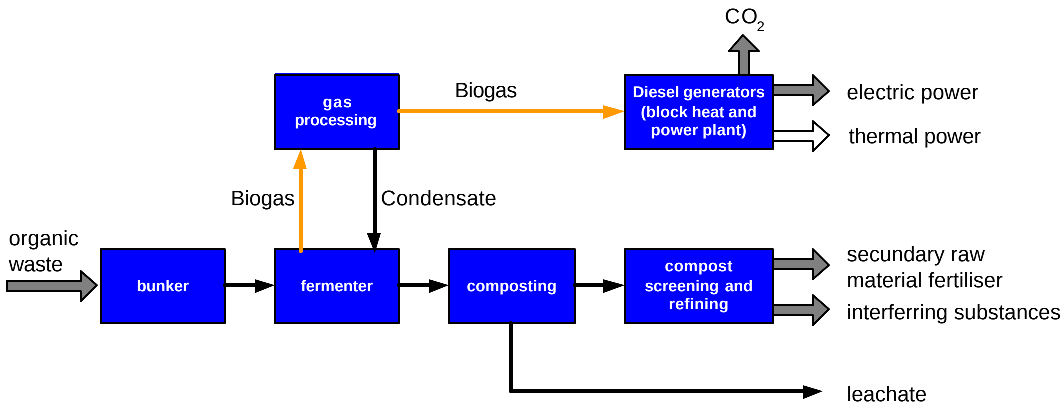


Figure 4-6: Simplified flow chart of a dry fermentation process

4.2.1.1 Description of Technology

The BEKON dry fermentation process is a batch process. The process distinguishes itself through relatively simple construction of the fermentation plant, a minimum of vulnerable mechanical components, low energy consumption and high resistance to interfering substances.

A BEKON dry fermentation biogas plant typically consists of a bunker for substrate storage, a number of fermenters and a block heat and power plant. The size, number and capacity of these components depend on the amount of substrate available at the location.

The technology of "dry fermentation" can generate energy from communal and agricultural organic matter / waste. Up until now, biogas technology is mainly concentrated on the "wet fermentation" of agricultural and communal organic waste, while the recently patented BEKON dry fermentation process can produce methane from organic matter with a high content of dry matter. In the following we will briefly go through the general technological aspects of this specific process.

The substrate (communal and agricultural organic waste) delivered to the dry fermentation site where, if necessary, it is temporarily stored in the bunker. A main characteristic of this dry fermentation process is, that the input material can be used without further separation and pre-treatment.

The substrate is then mixed with already fermented matter that has been in one of the fermenters for several weeks. This is simply done on a tarmaced surface outside the fermenters with the help of a wheel loader. Mixing, pumping and stirring equipment is not needed, which reduces costs for investment and maintenance. One fermenter at a time is emptied and refilled in this fashion.

The BEKON dry fermentation process, which is a single-stage batch process, consists of several compounds as shown in Figure 4-7.

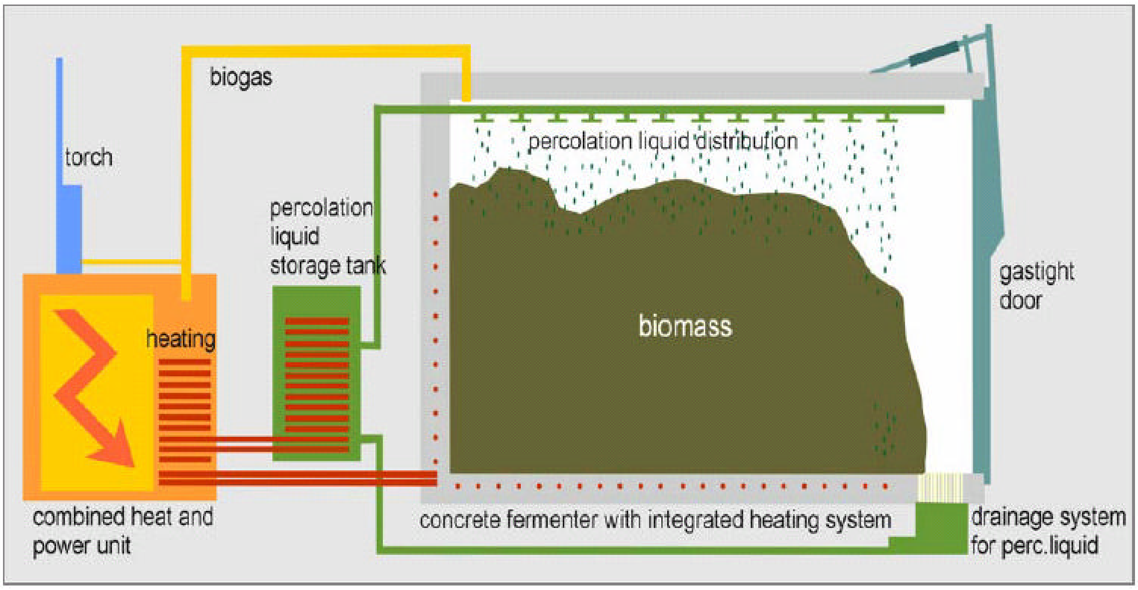


Figure 4-7: BEKON dry fermentation system

As shown in the figure above the biomass simply lies in the fermenter where it is percolated with the liquid gathered from the biomass and heated by the combined heat and power unit. This unit generates the heat required for the fermenters and the percolation storage tank, as well as electricity from the biogas that is generated in the fermenters. This kind of energy production is environmentally sound and economically interesting, while also creating and securing employment.

Instead of disposing of organic matter from agriculture or communal waste in other ways, dry fermentation offers a means of turning it into a valuable resource and extracting the highest possible benefit from it (biogas, electricity, heat, compost and fertilizer).

4.2.1.1.1 Substrate

Type of Substrate

Biomass resources of Phu Quoc include 4 main groups: (i) waste from plants; (ii) residues from wood processing industry; (iii) waste from people and animals; and (iv) residential waste. As indicated in the framework conditions above the substrate resource that can easily be collected for the generation of renewable energy by biogas plants in Phu Quoc is the residential waste.

Residues from plants for biogas production include post-harvest residues such as from sweet potatoes, cassava, vegetables and some industrial tree plantations as well as trees from natural forests. However, in order to use these residues for production of RENEWable energy by biogas plants, one has to remember that only biomass with low lignin content is suitable. The share and concentration level of residues from plants with low lignin content and is not high.

Table 4-2: Composition of waste to be used for renewable energy generation[28]

Components	TOTAL waste (2005)		Organic	Inorganic	Mineral
	(%)	(tons)	(%)	(%)	(%)
Paper	*4.37%*	*684*		*4.37%*	
Glass	*2.38%*	*373*			*2.38%*
Metal	*1.28%*	*200*			
Plastic sac	*8.05%*	*1260*		*8.05%*	
Food waste, vegetable waste	*53.36%*	*8354*	*53.36%*		
Garden waste	*3.08%*	*482*	*3.08%*		
Shell, hulls, peel	*10.77%*	*1686*	*10.77%*		
Wood waste	*0.72%*	*113*	*0.72%*		
Bone, shell...	*2.55%*	*399*			*2.55%*
Ceramic waste, brick	*3.92%*	*614*			*3.92%*
Clout	*1.69%*	*265*		*1.69%*	
Shoes, sandal…	*1.54%*	*241*		*1.54%*	
Pin...	*0.01%*	*2*			
Other	*6.39%*	*1000*		*6.39%*	
Total	***100.00%***	***15656***	***67.92%***	***22.04%***	***8.85%***

The solid waste of Phu Quoc island, especially the solid waste from hotel, restaurant, comprises mainly bio-waste (around 60% is biodegradable waste).

[28] BiWaRE (data inventory 2004)

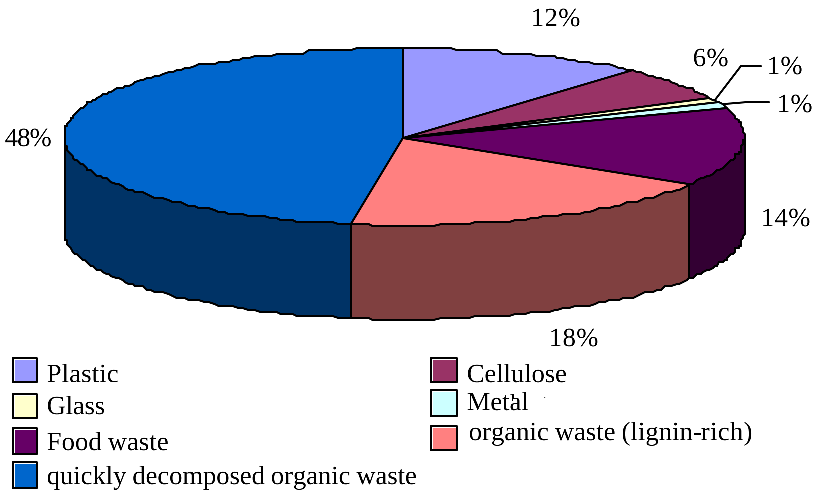


Figure 4-8: Components of hotel, restaurant solid waste at Phu Quoc[29]

Together with the socio-economic development and urbanization increase, Phu Quoc creates an increasing amount of solid waste every year. However, with the slow development of industry at present the residential waste will remain a main share of solid waste on the island.

<u>Quantity of Substrate</u>

Waste from households

According to the previous estimations[30], the amount of waste produced by one person in Vietnam is situated between 0.3 kg/(person*day) in rural areas and 0.7 kg/(person*day) in big cities. For Phu Quoc, an average of 0.5 kg/(person*day) was considered for the year 2005, with an increase up to 0.7 kg/(person*day) for 2025. This increase can be justified by the expected improvement of lifestyle conditions (increase in population's income and consumption), simultaneous with the socio-economic development of the region in the next years.

Thus, the yearly rate of household waste produced by the population of Phu Quoc in 2005 can be calculated as follows (for the calculation a 100% collection rate of waste was assumed):

85,000 x 0.5 x 365 = 15,512,500 kg ˜ 15,512 tons (2005)

Taking into consideration the average population growth ratio of 5.3% and the increased ratio of waste per capita and day of 0.7 kg, the expected amount of waste in 2025 would be:

238,700 x 0.7 x 365 = 60,987,850 kg ˜ 60,988 tons (2025)

[29] BiWaRE (data inventory 2003)

[30] World Bank 2004

Waste from tourists

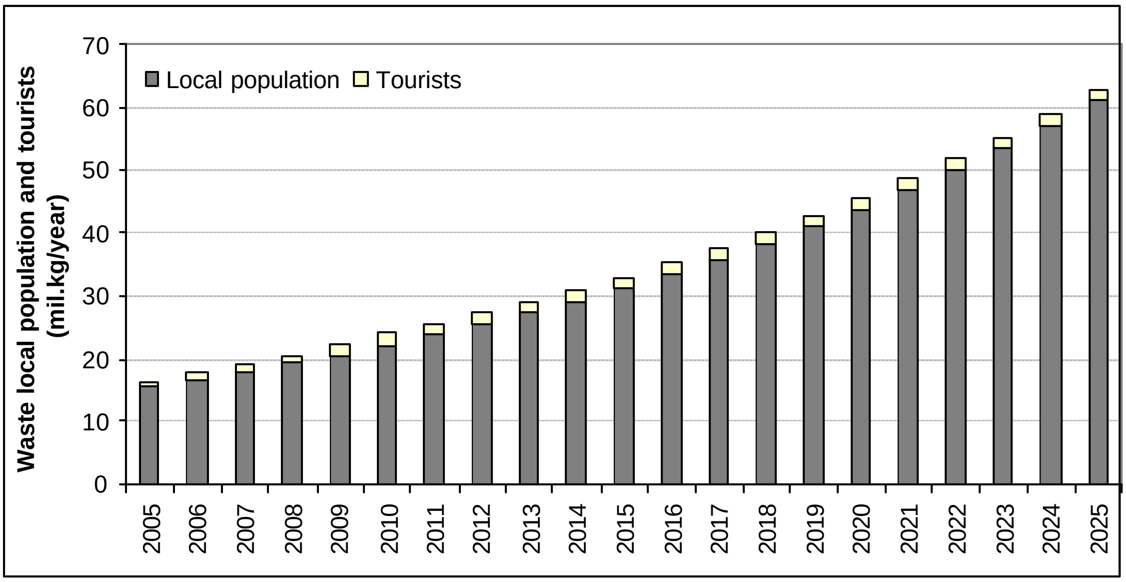
Apart from the waste produced by local population, the tourists will contribute a significant amount of waste. The average stay duration of a tourist is 3-4 days (Phu Quoc District Report, 2004). The daily amount of waste produced by the tourists is considered to be about 1.2 kg/(person*day), ca. double than local residents (World Bank, 2004) and thus the yearly estimated rates:

- Waste produced by tourists in 2005:
  220,000 x 1.2 x 4 = 1,056,000 kg ˜ 1,056 tons (2005)
- Waste produced by tourists in 2025:
  500,000 x 2.0 x 4 = 4,000,000 kg ˜ 4,000 tons (2025)

The total amount of waste produced on Phu Quoc Island from local population and tourists will be:

- 2005: about 16,568 tons
- 2025: about 64,988 tons

Figure 4-9: Estimation of total waste production for 2005 – 2025 (local population and tourists)



Waste from seasonal workers

Due to difficulties in estimation of number of seasonal workers from areas such as construction, fishery, agriculture and other branches, the total amount of waste produced on the Phu Quoc island was evaluated to increase by 5%. The estimation is very general and the final number may vary due to the climatic changes and economical perspectives.

The total amount of household waste, including the waste produced by the seasonal workers is:

- for 2005: 16,568 tons x 1.05 = 17,396 tons
- for 2025: 64,988 tons x 1.05 = 68,237 tons

Waste from animals

The source of wastes from animals includes mainly from excrement of raised animals such as pigs, buffaloes, cows, and poultry. As of the end of 2004, Phu Quoc has about 15,000 pigs, 2,900 cows and 100,000 fowls. Total potential of this resource is assessed as follows:

Table 4-3: Source of animal excrement to be used for the generation of energy in Phu Quoc (2004)[31]

Source	Quantity (animals)	Waste amount (tons/year)	Potential production of biogas (m^3/year)
Pigs	15,000	14,235	711,750
Cows	2,900	18,524	555,712.5
Fowls	100,000	912.5	54,750
Total			**1,322,213**

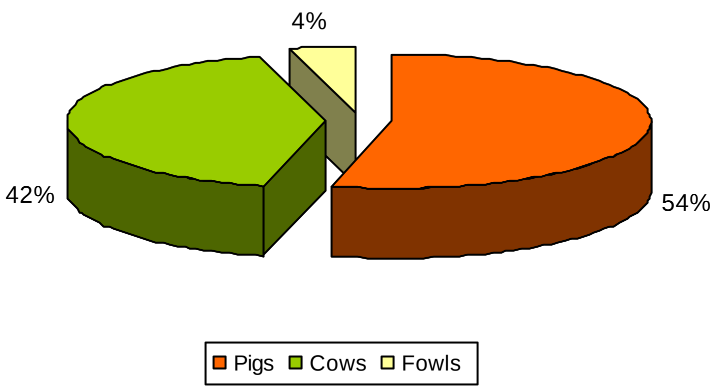


Figure 4-10: Potential of biogas by type of animal excrement sources

Among the waste sources from animals mentioned above, only waste from pigs is highly concentrated. It may be found in the households having large scales of husbandry. However, the maximum for each household is only at 15-20 tons of substrate per year.

These small amounts are generally used for the own or neighbouring crop farming. Most of these small scale farmers (seeFigure 4-11) have no collection facilities, yet.

31 Assessment by study team – Institute of Energy, Hanoi

Figure 4-11: Small scale husbandry on Phu Quoc (IKrW, December 2005)

Thus, a suitable system of collection and transport would have to be implemented as a pre-condition for using this kind of substrate economically.

Waste Collection

According to the report of the Public Project Management Board and Department of Natural Resources And Environment of Phu Quoc district, the amount of waste which has be collected in recent years has increased as reflected in Table 4-4. The collected waste comes mainly from residential areas such as two towns Duong Dong, An Thoi and Ham Ninh commune.

Table 4-4: Total quantity of solid waste generated and collected from 2001 to 2004[32]

Year	Total quantity of solid waste (ton) [estimation number]	Total quantity of solid waste collected (ton)	Collection ratio (%)
2001	13728	5886	42.9
2002	14086	7200	51.1
2003	15170	8972	59.1
2004	15210	13080	86.0

32 Public Project Management Board, Phu Quoc

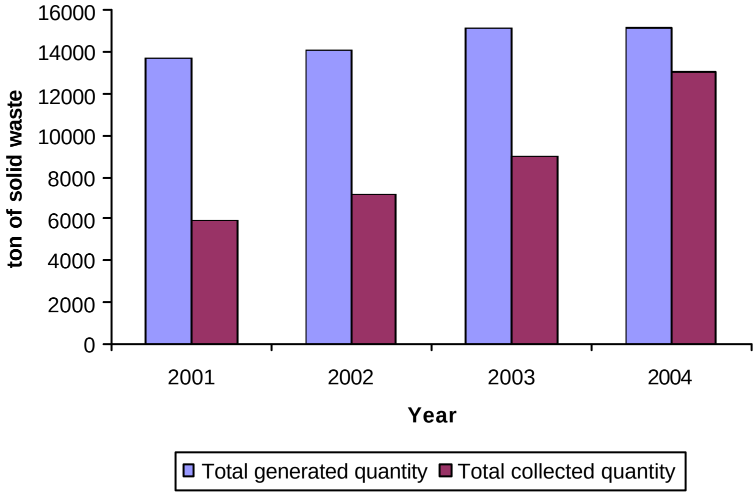


Figure 4-12: Total quantity of solid waste generated and collected at Phu Quoc

According to the forecast of the Phu Quoc island Environment Resource - Traffic - Construction department, the quantity of waste will increase on the average of 3000 tons per year during 2005-2010. The main causes for this increase are urbanisation, population growth and the changing of the consumer's attitude.

The estimation below of the Environment Resource - Traffic - Construction department is mainly based on the population growth and number of tourist as the following:

- In 2005, Phu Quoc had 88,304 residents and 220,000 tourists with an average stay of 3 days having a solid waste generation rate of 0.5 kg waste/person*day. Therefore, the total quantity of solid waste generated in 2005 is:

  $(0.5 \times 88{,}304 \times 365) + (0.5 \times 220{,}000 \text{ x } 3) = 16{,}445{,}000$ kg = 16,445 tons

- In 2010, Phu Quoc will have 120,700 residents and 500,000 tourists with an average stay of 4 days having a solid waste generation rate of 0.7 kg waste/person*day. Therefore, the total quantity of solid waste generated in 2010 can be estimated as following:

  $(0.7 \times 120{,}700 \times 365) + (0.5 \times 500{,}000 \text{ x } 4) = 31{,}838{,}000$ kg = 31,838 tons

Please note that these numbers differ from the estimation given earlier. This is due to the fact that each prediction of future waste production will vary depending on the number of people and tourists assumed as well as their change in waste production habit. There is no such thing as the right prediction unless we know the actual value, which we cannot as it lies in the future.

Development of substrates

According to the report of the Public Project Management Board and Department of Natural Resources And Environment of Phu Quoc district, the amount of waste which was collected in recent years has increased. The collected waste comes mainly from residential areas such as two towns Duong Dong, An Thoi and Ham Ninh commune.

A higher collection rate is estimated for 2005 with 90% and considered to increase in the following years up to 95%.

According to the assessment of the Department of Natural Resources and Environment - Construction and Transport of Phu Quoc district, in coming period, the residential waste in Phu Quoc will be increased as follows:

Table 4-5: Anticipated residential waste of Phu Quoc for the generation of renewable energy in the period 2005-2010[33]

Year	Total estimated waste amount (tons)	Share of collection (%)	Annual collected waste amount (tons)
2005	16 445	90	14 800
2010	31 838	95	30 246

As a matter of fact, estimations are changing in a certain range depending on sources (e.g. authorities) and comparisons with similar regions (national authorities, World Bank). Therefore, the amount of substrates used as basic load in this feasibility study, was chosen to be 15,000 tons. According to the estimations made above, the annual waste amount for 2010 will be approx. 30,000 tons rising up to 60,000 tons until 2025.

Energy Content of Substrate

For solid substrates (manure, biomass, waste) which are utilised for biogas generation, the following parameters are relevant:

- specific methane yield.
- dry substance content (DS)
- organic dry substance content (oDS).

33 Department of Natural Resources and Environment, Construction and Transport & Study Team of IE

The specific methane yield is a measure of the quantity of methane which is produced from a particular substrate. Depending on its composition the biogas yields can vary widely. As Table 4-6 shows, the biogas yield and methane content differs for carbohydrates, proteins and lipids.

Table 4-6: Specific biogas yield and methane content for substrate compounds[34]

	Biogas yield [m³/kg oDS]	Methane content [Vol %]
Digestable proteine	0,6 – 0,7	70-75
Digestable lipids	1 – 1.2	68-73
Digestable carbohydrates	0,7 – 0,8	50-55

For biogas plant planning, not the total methane yield, but the methane yield which refers to typical retention times in biogas plants is of interest, when the degree of degradation typical lies in the range of 40-50%[35]. For different types of substrates, typical values can be taken from literature (Table 4-8).

Substrates utilised in biogas plants consist of water, organic material and inorganic material, but only the actual *organic substance* of the substrate is degraded to biogas (Figure 4-13). Therefore the specific biogas and methane yield of a substance is largely influenced by the water content and the content of organic substances. As a consequence, the specific methane yield should refer to "organic dry substance" and normally is expressed as *"m³ methane / kg organic dry substance".*

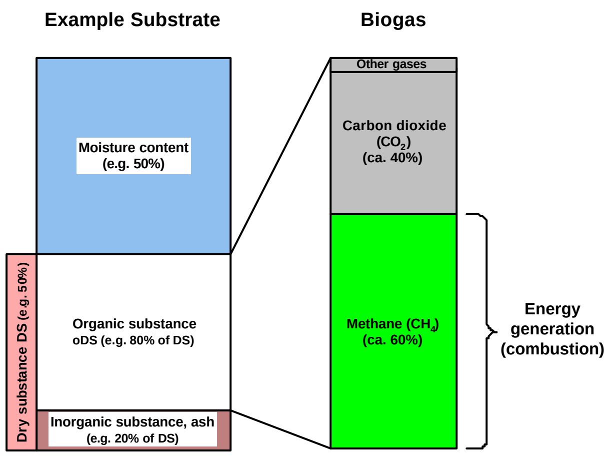


Figure 4-13: Composition of substrates and biogas formation

The **content of dry substance (DS)** is the water free fraction of the substrate (Figure 4-13). The DS is analysed by drying at 105 °C. Typical values are 6-17 % (for cattle manure) or 40-75 % (organic waste).

[34] Weiland, 2001
[35] Loll, 2001

The water free fraction of the substrates (dry substance content) consists of organic and inorganic material (Figure 4-13). The **organic dry substance content (oDS)** is a measure for the organic content, which can be degraded biological or combusted. The oDS is expressed as "% of DS". The oDS is analysed by heating the substrate to 550°C, so that the organic material is volatilised and the inorganic content (ash) is left.

To be able to calculate the biogas yield for the original wet substrate as supplied to the biogas plant, the water content and organic content need to be considered. If chemical analysis is not possible, typical values from literature can be used (Table 4-7). However it must be noted, that great variations is possible, which might have a big effect on the result.

Table 4-7: Characteristics of solid biogas substrates (selected values)

Substrate	**DS** [% by weight]	**oDS** [% by weight, of DS]	**Specific CH_4-yield** [CH_4/kg oDS]
Agro based crop substrates			
Beet tops	16-17	75-80	0.30-0.83
Beet, sugar beet	23	90-95	0.42-0.46
Beet, forage beet	16	85	0.48
Beet (Gehaltsrübe)	12-15	75-85	0.33-0.45
Clover	20	80	0.26-0.50
Grass	15	80	0.17-0.33
Grass silage	21-54	76-95	0.30-0.60
Grass sil. (1st. Crop, bloom)	35	89.8	0.30
Maize silage	20-35	85-96	0.22-0.50
Maize straw	86	72	0.60-0.70
Potato tops (Kartoffelkraut)	25	79	0.17-0.60
Rapeseed shred	91		0.40-0.90
Wheat straw	86	92	0.12-0.19
Animal husbandry			
Cattle manure	6-17	72-90	0.10-0.35
Cattle manure (with straw)	12-40	65-85	0.13-0.46
Chicken manure	10-34	70-80	0.19-0.72
Chicken manure (with straw)	20-32	63-80	0.15-0.29
Horse manure (with straw)	28	25-75	0.12-0.40
Pig manure	3-13	52-86	0.18-0.64
Pig manure (with straw)	20-25	75-82	0.16-0.27
Sheep manure (with straw)	25-30	80	0.05-0.50

Substrate **Municipal and industrial waste**	**DS** **[% by weight]**	**oDS** **[% by weight, of DS]**	**Specific CH_4-yield** **[CH_4/kg oDS]**
Animal cadaver meal	8-25	90	0.50-0.80
Biowaste	40-75	30-70	0.09-0.60
Cereal mash	6-10	83-90	0.26-0.60
Clippings (sedge) (Mähgut)	30-37	91-94	0.48-0.50
Fat (from fat separators)	2-70	75-98	0.36-1.00
Filtration silica gel (beer)	30	6	0.30-0.35
Float fat	5-35	95-98	0.70-0.80
Flotation sludge	5-24	80-98	0.58-0.78
Foliage / leaves	30-85	75-85	0.13-0.40
Food waste	9-40	50-98	0.12-1.00
Fruit pulp (fresh)	13	90	0.39-0.45
Kitchen waste	9-37	75-98	0.50-0.60
Loppings	12-90	25-92	0.29-0.58
Market waste	5-25	76-90	0.25-0.37
Mash of apples	2-3	95	0.33
Mash of fruits	2-7	85-95	0.24-0.42
Molasse	80-90	85-95	0.26-0.35
Oil seed residue (pressed)	92	97	0.58-0.62
Pomace of apples	25-45	85-90	0.30-0.45
Pomace of fruits	22-50	60-95	0.30-0.48
Pomace of grape	40-50	80-95	0.42-0.45
Potato mash	6-15	81-95	0.24-0.55
Potato pulp	12-16	90-94	0.24-0.55
Potato slop	12-15	90	0.24-0.55
Raps extraction residue	86-93	90-94	0.40-0.60
Rumen content (pressed)	20-45	80-90	0.60-0.70
Rumen content (untreated)	11-19	80-94	0.12-0.40
Sewage sludge (liquid)	3-8	40-70	0.31 (0.19-0.44)
Spent grains from beer	15-25	70-95	0.30-0.70
Spent hops (dried) (Hopfentreber)	97	90	0.50-0.55
Stomache contents (pig)	11-19	75-88	0.16-0.30
Straw	60-90	70-85	0.15-0.20
Vegetable waste	5-25	75-90	0.20-0.66
Whey	80-95	80-95	0.30-0.60
Yard trimming		15-75	

Most data on biogas or methane yield in literature are expressed in "m³", so it can be assumed that they refer to prevailing conditions of the time of measurement. Therefore it is suggested to convert biogas yields to norm conditions. The volume of gases (i.e. biogas) depends on the ambient conditions, i.e. gas temperature and atmospheric pressure. Therefore gas volumes should be expressed in Nm³ (= '**Norm cubic meter**"), which refers to norm conditions (0°C, 1,013 hPa) to avoid too optimistic or pessimistic prognosis on the energy yield. Norm cubic meters can be calculated as following:

Calculation: "Conversion into norm gas volume"

$$V_N = \frac{V_G * (P_L - P_R) * 0,269}{(273 + T_G)}$$

where:

V_N = norm volume [Nm³]
V_G = gas volume [m³]

P_L= atmospheric pressure [hPa], e.g. 960 hPa

P_R= negative pressure in gas flow control system (Gasregelstrecke)

T_G= gas temperature [°C], e.g. 30 °C

Long Term Contracts with Suppliers

The agency which is responsible for collecting, transporting and managing residential waste of Phu Quoc is established on 22/8/1998. It is titled *Public Project Management Board*.

The collecting means of Public Project Management Board include waste collecting vehicles, hoes for burring waste. These vehicles are manually operated in narrow roads and public waste bins. Because of weak infrastructure, especially transport system, collecting waste is carried out only in two towns Duong Dong and An Thoi, but even there not completely. In general, additional investment in and renovation of equipment for collection and treatment is now not paid enough attention to. The manpower and facility of Public Project Management Board cannot meet the requirements of the collection of waste in narrow streets and alleys.

Total number of employees of Public Project Management Board is 52 persons of which 47 are contracted workers working based on the two budget resources: (i) fees of hygiene contributed by households (according to Decision No. 55/23/QD-UB dated 08/5/2003 by the People Committee of Kien Giang province); and (ii) district budget. Of which the hygiene fees (i) are used for paying salary to contracted workers, procurement of safety tools. The annual budget provided by the district (ii) is used for office staff, investment in equipment, and large construction repairing etc.

In the other communes of Phu Quoc, at present, there is no manpower for collecting waste. In future, this manforce is anticipated to establish and carrying out the work with hygiene fees from people contribution and one additional budget provided by the commune authority.

Therefore, in order to ensure long term supply of substrate for production of renewable energy from organic waste and biomass by biogas plants on Phu Quoc, two options will be considered as follows:

(1) Through the contracts signed directly between power plant and communes of Phu Quoc island district for continuous supplying residential waste to the power plant. Based on these contracts, communes of Phu Quoc will establish teams for collection of residential waste, solving environmental problems related to waste in the communes. This will reduce hygiene fees for households in the communes where most households are poor. However this option is not as good as the following second option in terms of legal aspects.

(2) Through long term contract with Public Project Management Board of Phu Quoc: The fees of this contract will be used for operation of the Board. This is the third budget, helping Board increase ability to invest in modern equipment and expansion of waste collection network through subcontracts with workforces in various localities of the district. This activity will contribute in stabilization of waste supply. The substrate selling price at biogas power plants for energy production will be agreed between energy producer and Public Project Management Board Phu Quoc island district.

Established according to the Decision No. 2716/QD-UB by People Committee of Kien Giang province and based on urgent environmental requirements, Public Project Management Board of Phu Quoc is an important organisation for common development process of this tourist island. Therefore, this is the institution which is able to perform a long term contract on supplying substrate resource for biogas production.

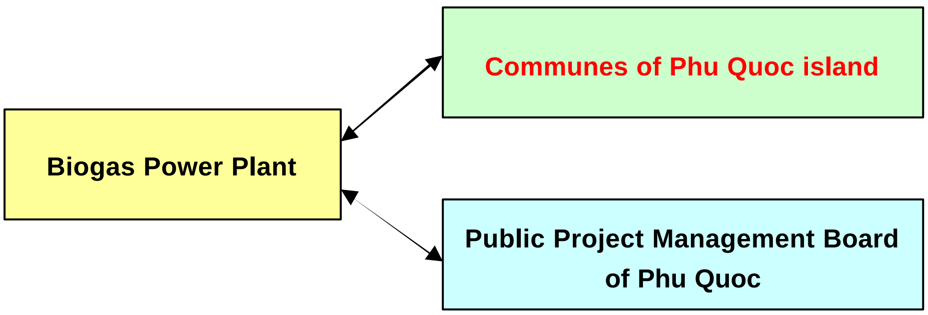


Figure 4-14: Long term contracts on supplying substrate for operating biogas power plant

4.2.1.1.2 Process Dimensioning

The proposed **system**, the BEKON dry fermentation process, consists of the main components listed below:

- A number of fermenters built for 15,000 tons of household waste annually (these are concrete build with gas tight sealed doors; the typical dimension is 5.9m x 5m x 29m per fermenter; the fermenters are heated via the heat exchange connected to the combined heat and power unit)
- Combined heat and power unit for a 500kW capacity (space requirement at least 20 m^2)
- Open tarmac area for mixing of fresh and old substrate (the surface includes some drainage); additional tarmac area for after maturing of the old substrate (post fermentation maturing)

- Bunker for temporary storage of the household waste before fermentation (build to keep app. 300 tons of waste, the weekly share of the annual amount of 15,000 tons)
- Percolation liquid tank, typically no more than 8 m in diameter
- Process control facilities (room for gas meters, computer based control facilities and other control panels)

For the BEKON dry fermentation process one can assume the following **availabilities**. The combined block heat and power unit will be available for 95% of the time. The working time of the combined heat and power unit is given in working hours per year. Thus an availability of 95% is equivalent to 8322 working hours per year.

The **capacities** are estimated as follows. The 15,000 t/a of household waste have 35% of dry substance (which is 5250 t/a) of which 80% will be organic dry substance. The organic dry substance has a specific biogas production rate of 0.4 m^3/t. These are the measures that are important for the actual energy generating content of the waste. Given these one can estimate that the bock heat and power unit will produce 364 kW this is equivalent to 3,192,000 kWh/a. This number is lower than the kW assumed earlier for the system. This is down to the rather conservative estimate for the amount of household waste and its increase over time as given in the arguments below.

The amount of available waste assumed for these calculations is well below the numbers estimated by the Environment Resource - Traffic - Construction department. The lower number is assumed in order to cope with the following facts:

(1) Seasonal unavailability of substrates due to strong increase of wastes during tourist season

(2) Unexpected factors that might lead to a slower increase in the collected waste due to lack of the necessary infrastructure

(3) Other factors that might contribute to a lesser rate of household waste increase are a lesser population increase or a slower increase in the populations waste production habits.

It is thus recommended to build a biogas plant with components suited to these varying factors. Careful planning of the exact numbers of system components will enable one to ensure a continuing energy generation even if substrates, i.e. household waste, should be sparse at times.

4.2.1.1.3 Energy Generation and Distribution

As already described earlier the production of energy in a biogas plant is via the biogas that escapes from the biomass in the fermenters. How efficiently this biogas is used, i.e. how much of it is converted into energy depends on the combined heat and electricity unit. Commonly the same amount of biogas is utilised for electricity as for heat. Most combined heat and power units cannot utilise between 20 and 30% of the biogas. This loss of efficiency however is independent of the type of fermentation used. It is a rather general problem with all gas combusting heat power units. The **production of electric energy** is looked at in more detail below.

The fresh substrate (organic matter / waste) is inoculated with old substrate that has already been fermented. It is then filled into the fermenter and fermented under airtight conditions. Continual inoculation with bacterial matter occurs through recirculation of percolation liquid, which is sprayed over the organic matter in the digester. No stirring of the organic matter is necessary during the dry fermentation process, as it is in conventional wet fermentation systems.

The temperature of the process and of the percolation liquid are regulated by a built-in floor heating system in the digester and a heat exchanger in the tank which acts as a reservoir for the percolation liquid. The necessary heat is generated via the combined heat power unit.

The different stages of degradation (i.e. hydrolysis, acid and methane formation) take place in the same fermenter, which has a lot of advantages in comparison to other systems, where usually considerably more expense is involved in respect to the process itself and in respect to the mechanical technology behind it. This in turn has an adverse effect on process energy consumption and on maintenance costs.

The biogas is captured and burnt in the heat power unit. The heat from the burning of the gas is used to boil water; the steam from this process then turns a turbine through which electricity is generated. One can expect from the numbers given above a minimum of 170 kW electric energy production. During this process a lot of heat is generated, this heat does not escape unused, how exactly it is utilised is described below.

The **thermal energy produced** in the combined heat and power unit is a by-product of electricity generation. The amount of heat energy that is utilised in such a unit is highly dependent on the type of unit used. The generator in which the biogas is burned to produce steam that generates electricity via a turbine produces a lot of heat. The heat is captured in water so that a heat exchange takes place. There are several sources of heat on a power unit that can be exchanged or captured each manufacturer has their own way of maximising the energy efficiency. One can estimate a 200 kW production of heat energy from a plant of the size assumed above.

Comparison of Energy Demand with Energy Production

The existing electricity plants on Phu Quoc have produced an increasing amount of electricity each year, from 3,821 MWh in 1998 to 18,312 MWh in 2004 (see Chapter 3.4.1 for more details). This increase reflects the increasing demand on the island, however it is difficult to determine this demand for the future with precision. The energy demand of the island will increase in the future.

According to the *“The general plan of construction Phu Quoc district – Kien Giang province- to the year 2020”,* the total of electric power supplied on Phu Quoc island has to reach 50 MW in 2010 and 150 MW in 2020. The anticipated electricity supplies for each of the main consumption sector are as follows:

- Domestic sector: 1500 kW/person*year
- Industry sector: 250 kW/ha
- Tourist sector: 2–3 kW/bed

Today not all households on Phu Quoc are connected to the electricity grid and the demand will clearly also depend on how strongly the population size increases and to what extend households are connected to the grid network.

Given the estimated energy generation above it looks as though it will not be possible to substitute one of the existing diesel generators on the island. However as the estimate considered here is particularly low and the household waste generation is expected to increase in the future it will be possible to replace the capacity now generated by one of the diesel generators.

4.2.1.1.4 Land Requirement

Based on the system dimensions given above one can estimate the land requirements of the BEKON dry fermentation process. Given the size of the fermenters and the need for a temporary storage bunker as well as open tarmac areas for mixing and post-fermentation maturing the land requirement is assessed to be approximately 3,000m^2. This includes all control facilities, percolation tank and room for substrate deliveries.

4.2.1.1.5 Process and Maintenance

The BEKON dry fermentation process is a rather simple process of biogas generation. As a batch process the emptying and refilling of individual fermenters needs to be done in regular intervals, but once a fermenter is filled the process of percolation and heating is automatic so that it can essentially be left until it is emptied again. The amount of refilling needed depends on the number of fermenters and the fermenting time best suited for the local conditions.

Generally there is very little maintenance required for the BEKON dry fermentation process. All components are build to last and show little areas for fast occurring wear. The main issue is to ensure that no leakage takes place. If there is any leakage where gas does escape this is noticed early as the computerised control system shows the drop in gas production clearly. The combined heat and power unit however does require regular checks. Like other generating plants the oil needs to be checked regularly and the mechanics have to be thoroughly maintained on a regular basis,

4.2.1.1.6 Interfaces with Existing Systems

Introducing BEKON dry fermentation process into the existing system of Phu Quoc has several consequences. Almost the total of the generated household waste can be treated in the dry fermentation process and it is relatively easy to increase the capacity of the plant if there is an even stronger increase of waste the anticipated. Due to the pre-treatment of household waste the energy captured in its organic components can be utilised in a very efficient way. The methan that is produced in the decomposition process is captured and converted into energy. This does not only represent an environmentally sound option because the energy generated this way is renewable energy but also because the methan a green house gas that would otherwise escape into the atmosphere is prevented from doing so. The final amount of non-degradable waste that does need to be landfill is considerably smaller than the amount that was collected from the households.

Due to the use of household waste the existing waste management facilities will be improved considerably. This is because the waste receives economic value when it is reused in this way. Where earlier it was mindlessly dumped and not managed at all it now becomes economically important to collect and manage it.

4.2.1.1.7 Comparison to other Existing Plants

Other types of biogas plants than dry fermentation plant are the wet fermentation plant or a combination of dry and wet fermentation. Wet fermentation plants usually process sludge or sewage water in addition to manure and or organic waste. Wet fermentation plants doe require a greater amount of mechanical components as it is important for the fermentation process that the solid part of the biomass does not separate from the liquid part. This often makes substrate pumps and stirrers a necessity. Due to this additional equipment the whole process is much more sensitive to interfering substances.

The choice of fermentation type can only be made according to the substrates available. If the the majority of the substrates are liquid a wet fermentation is surely preferable. With more dry substrates available the choice would be a dry fermentation plant. Below are some of the pros and cons for dry and wet fermentation.

Solid substrates can be treated in wet and dry fermentation plants. Because of thorough mixing and small particle size of the substrate in wet fermentation the retention times are shorter than in dry fermentation. By increasing retention times in dry fermentation, however, substrate specific biogas yields equal to those of wet fermentation can be achieved.

The advantage of BEKON dry fermentation lies in its significantly lower energy requirements to most wet fermentation plants. The little to no stirring of the substrate in the reactors of the dry fermentation process makes methane production here less sensitive to disturbances. To facilitate the effective distribution of locally formed high acid concentrations that occur in dry fermentation it is important that the substrate contain structure-rich components which promote uniform flow. While in the wet fermentation one must take care that the methanogenic biocenosis is not washed out, dry fermentation, with percolation and/or retention of fermentation liquor, can be viewed as a kind of fixed-bed reactor in which the percolate is circulated and the substrate also serves as a carrier for microbial growth.

In addition, one can expect from dry fermentation (here BEKON) that absence of substrate pumps and stirrers will result in lower costs for repairs and maintenance than with wet fermentation, at least in so far as solid substrates are used.

In evaluating wet fermentation plants, the wide range of substrates they can handle is to their advantage. When large volumes of liquid or semi-solid substrates are to be treated, wet fermentation is probably the right choice. However, if large amounts of straw, hay, or substrates with a high proportion of interfering substances (sand, foils, etc) are to be used, dry fermentation offers clear advantages.

Dry fermentation's low electricity requirements and high tolerance of interfering substances indicate its great potential in the development of eco-efficient fermentation processes.

Given this information it becomes again obvious that why the BEKON dry fermentation is such a desirable option for the island Phu Quoc. The substrates available at Phu Quoc suit this type of plant very well, the energy demand of the plant is low so are the maintenance requirements.

4.2.1.2 Utilisation / Disposal of Residues

There are two options dealing with the residue from biogas plant: disposing it at managed landfills or using it directly as fertiliser. This high quality compost, which results from the process of dry fermentation, is valuable for agricultural and horticultural purposes.

4.2.1.2.1 Quantity of Residues

The feasibility study on production of renewable energy for Phu Quoc by organic waste came to the suggestion that the household solid waste will be used to produce biogas for electricity generation by dry fermentation process. This process will generate residues that has to be estimated, to get an indication about the need for utilisation or disposal capacities as well as the respective revenues or costs.

The solid residue of a biogas process is called “slurry” or “digested sludge” and can be used as fertiliser. The digested sludge has been subject to anaerobic degradation in the biogas reactor. The initial input substrate is reduced by 24-80 % of the organic dry substance content, because the majority of the carbon compounds is degraded to methane and carbon dioxide [FNR, 2004].

The reduction of material depends on the degree of degradation, which again depends on the composition of the initial substrate and the process characteristics, like temperature, retention time and the organic loading in the reactor. For a course evaluation of the quantity of substrates, a **reduction of 50% of the organic dry substance** content can be assumed. The quantity of digested sludge can be calculated as following:

Calculation: “Conversion into norm gas volume”

$$m_{residue} = m_{substrates.total} - \left(\frac{m_{substrate\,total} * oDS_{substrate\,ave} * d}{100} \right)$$

where:

$m_{residue}$	=	mass of residues from biogas process [t/a]
$m_{substrates.total}$	=	total mass of substrates utilised [t/a]
$oDS_{substrate.ave}$	=	organic dry substance content of substrate mixture [%]
d	=	degradation rate [%]

The following data will be used for the above mentioned calculation:

Year	Total solid waste [ton]	Percent of solid waste collected [%]	Substrate for biogas pro-duction [ton]	Dry matter of substrate [%]	oDS of substrat e [%]	degradation rate [%$_{assumed}$]
2005	16445	86	14143	35	80	50
2010	31838	86	27381	35	80	50

Therefore, the total residue in the year 2005 is 12,163 tons and in the year 2010 is 23,548 tons.

4.2.1.2.2 Utilisation

The extensive agricultural activity of the island is leading to a high demand for fertiliser. Besides livestock manure, a great amount of conventional mineral fertilizer is used to cover the demand, with the use of residue from biogas plant as fertilizer Phu Quoc can reduce the imported mineral fertiliser.

In addition to the economic costs that are reduced when using the biogas plant residue as a fertilizer there is an environmental benefit from it. This is due to the fact that the main component of industrial fertiliser is phosphor, the natural phosphor resources are sparse thus building on alternative fertilizers in a growing agriculture is going to pay-off even more in the future.

4.2.1.2.3 Disposal

The second option is to dispose the residue at management landfill. Under anaerobic treatment most of organic matters were biodegraded, therefore the dispose of residue from biogas plant to landfill does not pose any risk for the environment.

With the landfill planned in the area of Ham Ninh the disposal of the fermenter content will be easy to realise from an infrastructural point of view. Given the restricted availability of land for landfill sites since Phu Quoc is an island the utilisation is clearly the preferable option.

4.2.1.3 Infrastructure

For the construction, the initial phase and the working of the fermentation plant basic infrastructure is needed. These include electricity and water supply as well as some consideration of wastewater treatment.

4.2.1.3.1 Electricity Supply

The village Ham Ninh is already connected to the main electricity grid of Phu Quoc. In addition to this the master plan for the development of Phu Quoc until 2020 includes the construction of a new airport close to Ham Ninh. This is planned in view of the increasing numbers of tourists.

Given that the biogas plant would be located somewhere between the village and the new airport the connection to the main electricity grid should be no problem with the development of the airport. Given the width of the South of the island the site of the biogas plant can be no further than 5km away from the airport.

Connection to the electricity grid is necessary for the construction phase of the plant. After the biogas production is started the plant will generated its own electricity and feed excess electrical power back into the main grid.

4.2.1.3.2 Water Supply

Similarly to the electricity supply the water supply at the suggested biogas plant site near Ham Ninh can easily be implemented when the supply for the new airport is planned.

The connection to water supply is especially important for the construction phase of the plant as the concrete construction and other building works require water. Once the fermentation process is started the water requirement of the plant is relatively low. The percolation liquid is gathered from the substrate and it is rarely necessary to add water for percolation. Further water requirements are for the basic sanitary equipment on site as well as cleaning of the fermenter doors and the mixing area.

4.2.1.3.3 Wastewater Treatment Facilities

During the BEKON dry fermentation process a small amount of wastewater is produced therefore facility for wastewater is needed. However the quantity of wastewater is small and quality of it usually no different to normal household wastewater, with the exception of the percolation liquid that can either be used as liquid fertilizer or disposed via soakaway as common in farming. This means that there is little or no need for additional treatment of the wastewater prior to letting it into the sewage system. This wastewater infrastructure will again be easily implemented once this part of the infrastructure is provided for the airport.

4.2.1.4 Storage and Logistics

4.2.1.4.1 Storage of Substrate

There are several substrate storage possibilities. This mainly depends on the future waste management of the island, the amount of collected household waste and the future location of the managed landfills. According to the master plan for Phu Quoc, a new landfill is planned in the area of Ham Ninh.

Given Ham Ninh as the preferred location for the biogas plant we know that this site will be well connected to the two major cities of Phu Quoc. Therefore one possibility is to transport the waste directly after collection to the plant site. Whether this is feasible or not depends on the waste management that is implemented and how well it works. It is vital for the energy production to has a constant supply of 290 tons of organic waste weekly. If this cannot be ensured then the production of energy cannot be guaranteed in a constant fashion. Thus the minimum requirement for this storage option is that the waste management is stable enough to supply the set amount of organic waste. If however there is to much waste generated on a weekly basis, say more than 320 tons, then the storage capacity at the biogas plant site will be insufficient and additional storage would be required. This additional storage problem can be solved if the new landfill is build nearby the biogas plant site.

With a landfill planned close by it is also possible to store the household waste on the landfill site and transport it to the biogas plant site whenever required. For this option it would be preferable to have landfill and biogas plant virtually side by side to minimise the transportation efforts. Independently of where the household waste is gathered, stored or landfilled outside the actual biogas plant site the plan for the BEKON dry fermentation site includes storage bunker to hold 300 tons of household waste.

4.2.1.4.2 Transport Infrastructure

Given the planned landfill site close to Ham Ninh some of the transportation infrastructure will be provided with it as the household waste that is generated at Phu Quoc will have transported to this site. Both the storage as well as the transportation depend on the future waste management of the island. The minimal amount of waste needs to be guaranteed to produce biogas continuously. If a significant proportion of the collected household waste is stored at a location different to Ham Ninh transportation infrastructure to and from this site needs to be in place. This means lorries need to be able to transport the household waste from managed landfills to the biogas plant site on tarmaced roads.

4.2.1.5 Summary of the Technical Assessment

The technical assessment of the option biogas plant for renewable energy production on Phu Quoc Island shows that the implementation of a BEKON dry fermentation process is technically possible. To summaries we will go though some of the aspects that where considered above.

The technology of the BEKON dry fermentation process is relatively simple and requires only little specialist knowledge this makes it a generally very attractive fermentation option. The substrates required to run the process are available on Phu Quoc. The available substrates are indeed substrates with high dry substance content (household waste) which again supports the recommendation to implement a dry fermentation process. It has also been shown that the amount of substrate present will be enough to ensure the feasibility of such a process and since the amount that is expected to increase it will even be more viable in the future.

The other requirements of the biogas plant are also evaluated as positive. The area needed for the plant is present in the location that was designated for the plant by the authorities. The process and maintenance requirements are low making the option attractive from a technical point of view. The process fits in well with the Islands future emphasis on environmental protection and renewable energy generation.

Additionally it is possible to utilise the substrate after fermentation as a fertiliser that would benefit the emerging agricultural industry of Phu Quoc. The infrastructure required for such a plant is going to be easily implemented with the other facilities like the airport and the new landfill which are planned according to the mater plan for Phu Quoc.

4.2.2 Economic Assessment

4.2.2.1 Investment Costs, Tax Depreciation/Amortization, Interest Costs, Repairs and Servicing

In order to specify relevant data for the economic assessment and associated costs of the implementation of a dry fermentation process for the treatment of household waste on Phu Quoc, Vietnam more precisely, a price estimate from the manufacturer of such dry fermentation plants was obtained. The choice fell on BEKON Energy Technologies GmbH & Co. KG, based in Munich/ Germany. BEKON, it is assumed, would be in a position to realize such a project under the special conditions prevailing in Vietnam.

The estimated investment costs, according to BEKON, would be approximately 3 million Euro (see Table 5-9). Additional costs would be incurred for a composting area, fencing, for planning and authorization, intermediate financing, and for unforeseen expenses, bringing total estimated investment costs to about 3.7 million euro.

In order to estimate the plant’s economic viability it was assumed that the plant itself and its operation will be refinanced from the generation and sale of electricity. To decide whether the construction and operation of a biogas plant for the fermentation of domestic waste makes economic sense, it is necessary to have information on the current cost price of electricity production on Phu Quoc. Since no such information is available, an estimate will be made of the minimum cost of producing electricity using generators powered by heating oil. It is assumed that such diesel generators are as efficient as the gas-powered generators intended for the biogas plant. Calculations were based on an assumed, relatively conservative, energy efficiency of 35 %. Estimating the fuel value of heating oil at 10 kWh/l, one litre will generate about 3.5 kW of electricity. If the average cost of heating oil fuel over the next 20 years is assumed to be about 0.60 € per litre, from fuel costs alone, one obtains a cost of 0.178 € per kWh of electricity. Since there will, of course, be additional costs for investment, repairs, servicing, personnel, etc., the cost price of generating electricity using heating oil powered generators on Phu Quoc will be more than 0.20 € per kWh.

In estimating the cost price of electricity production from the operation of the proposed biogas plant, the approach to determining “depreciation of plant” is based on the official tables for tax depreciation as usually used. The plant is written off over a period of 15 years. Since the case in question is of dry fermentation, the amount of machinery is less than in wet fermentation and investment in mainly in construction, the recovery period seems appropriate.

Table 4-8: Calculation of investment in the biogas plant to be constructed

No. of Pieces	Unit	Specification	Unit Price	Total Sum	Sponsor -ship	Investion Costs
		Construction				
0	m²	Property	-	-	0%	-
1	pc.	Secondary structure (fences, access)	25,000	25,000	0%	25,000
		Sum construction		***25,000***		***25,000***
		Fermentation				
1	pc	Dry fermentation plant, turn-key, incl. approval planning	3,000,000	3,000,000		3,000,000
1	pc	Surface sealing for composting area	150,000	150,000	0%	150,000
		Sum fermentation		***3,150,000***		***3,150,000***
		Sub-total		**3,175,000**		**3,175,000**
1	pc	Planning and permission	8.0%	254,000	0%	254,000
1	pc	Miscellaneous, unforeseen	5.0%	158,750	0%	158,750
1	pc	Interim financing	3.0%	95,250	0%	95,250
		Sub total		**3,683,000**		**3,683,000**
		Total sum		**3,683,000**		**3,683,000**

4.2.2.2 Budget of the First Twenty Years of Operation

Determination of the cost price of the electricity produced was conducted using a simplified profit and loss calculation applied to the first 20 years of operation.

Table 4-9 and Table 4-10 show the projected profit and loss calculation for the first 20 years of operation.

The estimate of costs for service and repair work for the individual structures and plant components was calculated on the basis of previous experience.

Interest charges were calculated on the basis of an interest rate of 6% per annum. For the years 2 to 20 an inflation rate of 2.0% per annum was assumed. This rate of inflation is applied generally (except to the costs of tax depreciation, loan interest and the plant's own energy supply) to all costs.

In the first year, the cost price, calculated from plant operating costs, of producing 1 kWh of electricity is estimated at 0.178 euro. However, since through the yearly repayment of 245,533 euro, the interest burden sinks faster than costs in general, because of the assumed 2% inflation rate, the cost price per kWh of electricity sinks year for year. After 10 years of operation, the cost price per kWh will have sunk to approximately 0.143 euro.

Cost effectiveness of the operating years 11 to 20 (based on the cost price of generating electricity), once half the recovery period has been passed, is even better than in the first 10 years. This is thanks to overcompensation of the inflation rate through the sinking interest burden and, from year 16 on, thanks to halving of the original tax depreciation rate, since here tax depreciation is only applied to plant which through reinvestment is written off after the original recovery period, when the rest of the plant is already written off. The cost price of electricity thus sinks in year 20 to 0.854 Euro per kWh. On average, the cost price of producing electricity over the first 20 years of operation is just 0.134 Euro per kWh, thus making the production of electricity from a dry fermentation plant for domestic waste considerably cheaper than its production from generators powered by heating oil.

So long as Phu Quoc is not connected to the mainland power grid, the production of electricity through the dry fermentation of domestic waste is, from an economic point of view, to be recommended. Besides the economic generation of electricity, there is, of course, also the environmentally friendly treatment of domestic waste and the reduction in green house gas emissions to be taken into account (compare Section 4.2.3.1).

Table 4-9: Profit and loss calculation for the first 10 years of operation

Budget (rate of price increases[1]): 2,0 %/a PROFIT AND LOSS ACCOUNT	year 1 [€]	year 2 [€]	year 3 [€]	year 4 [€]	year 5 [€]	year 6 [€]	year 7 [€]	year 8 [€]	year 9 [€]	year 10 [€]
sum turnover external	0	0	0	0	0	0	0	0	0	0
sum revenue from horticulture	0	0	0	0	0	0	0	0	0	0
TOTAL REVENUE	0	0	0	0	0	0	0	0	0	0
sum personal costs	39.000	39.780	40.576	41.387	42.215	43.059	43.920	44.799	45.695	46.609
sum waste disposal costs	0	0	0	0	0	0	0	0	0	0
sum depreciation[2]	245.533	245.533	245.533	245.533	245.533	245.533	245.533	245.533	245.533	245.533
sum insurance/contributions	15.000	15.300	15.606	15.918	16.236	16.561	16.892	17.230	17.575	17.926
sum repairs/maintenance	49.140	50.123	51.125	52.148	53.191	54.255	55.340	56.446	57.575	58.727
sum substrate costs	0	0	0	0	0	0	0	0	0	0
sum energy costs					own energy suppply					
sum costs of vehicles	20.000	20.400	20.808	21.224	21.649	22.082	22.523	22.974	23.433	23.902
sum advertising/travel costs	1.000	1.020	1.040	1.061	1.082	1.104	1.126	1.149	1.172	1.195
sum communication	1.000	1.020	1.040	1.061	1.082	1.104	1.126	1.149	1.172	1.195
sum office materials	1.000	1.020	1.040	1.061	1.082	1.104	1.126	1.149	1.172	1.195
sum further education, training/literature	1.000	1.020	1.040	1.061	1.082	1.104	1.126	1.149	1.172	1.195
sum legal and consultancy costs	1.200	1.224	1.248	1.273	1.299	1.325	1.351	1.378	1.406	1.434
sum costs of financial statement and audit	2.000	2.040	2.081	2.122	2.165	2.208	2.252	2.297	2.343	2.390
sum incidental bank charges	1.000	1.020	1.040	1.061	1.082	1.104	1.126	1.149	1.172	1.195
sum miscellaneous operating costs	10.000	10.200	10.404	10.612	10.824	11.041	11.262	11.487	11.717	11.951
COSTS	347.873	349.920	352.008	354.137	356.309	358.525	360.785	363.090	365.441	367.839
sum extraordinary income	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
OPERATING RESULT	-347.873	-349.920	-352.008	-354.137	-356.309	-358.525	-360.785	-363.090	-365.441	-367.839
sum interest (6 %)	220.980	206.248	191.516	176.784	162.052	147.320	132.588	117.856	103.124	88.392
FINANCIAL RESULTS	220.980	206.248	191.516	176.784	162.052	147.320	132.588	117.856	103.124	88.392
PROFIT BEFORE TAX	-568.853	-556.168	-543.524	-530.921	-518.361	-505.845	-493.373	-480.946	-468.565	-456.231
sum tax burdon (country specific)	0	0	0	0	0	0	0	0	0	0
sum tax benefits	-	-	-	-	-	-	-	-	-	-
SURPLUS/DEFICIT	-568.853	-556.168	-543.524	-530.921	-518.361	-505.845	-493.373	-480.946	-468.565	-456.231
specific power production costs [€/kWh]	-0,178	-0,174	-0,170	-0,166	-0,162	-0,158	-0,155	-0,151	-0,147	-0,143

Table 4-10: Profit and loss calculation for the years 11 to 20 of operation

Budget (rate of price increases[1]): 2,0 %/a PROFIT AND LOSS ACCOUNT	year 11 [€]	year 12 [€]	year 13 [€]	year 14 [€]	year 15 [€]	year 16 [€]	year 17 [€]	year 18 [€]	year 19 [€]	year 20 [€]	sum yr. 1 - 20 [€]
sum turnover external	0	0	0	0	0	0	0	0	0	0	0
sum revenue from horticulture	0	0	0	0	0	0	0	0	0	0	0
TOTAL REVENUE	0	0	0	0	0	0	0	0	0	0	0
sum personal costs	47.541	48.492	49.461	50.451	51.460	52.489	53.539	54.609	55.702	56.816	947.597
sum waste disposal costs	0	0	0	0	0	0	0	0	0	0	0
sum depreciation[2]	245.533	245.533	245.533	245.533	245.533	122.767	122.767	122.767	122.767	122.767	4.296.833
sum insurance/contributions	18.285	18.651	19.024	19.404	19.792	20.188	20.592	21.004	21.424	21.852	364.461
sum repairs/maintenance	59.901	61.099	62.321	63.568	64.839	66.136	67.459	68.808	70.184	71.588	1.193.973
sum substrate costs	0	0	0	0	0	0	0	0	0	0	0
sum energy costs											0
sum costs of vehicles	24.380	24.867	25.365	25.872	26.390	26.917	27.456	28.005	28.565	29.136	485.947
sum advertising/travel costs	1.219	1.243	1.268	1.294	1.319	1.346	1.373	1.400	1.428	1.457	24.297
sum communication	1.219	1.243	1.268	1.294	1.319	1.346	1.373	1.400	1.428	1.457	24.297
sum office materials	1.219	1.243	1.268	1.294	1.319	1.346	1.373	1.400	1.428	1.457	24.297
sum further education, training/literature	1.219	1.243	1.268	1.294	1.319	1.346	1.373	1.400	1.428	1.457	24.297
sum legal and consultancy costs	1.463	1.492	1.522	1.552	1.583	1.615	1.647	1.680	1.714	1.748	29.157
sum costs of financial statement and audit	2.438	2.487	2.536	2.587	2.639	2.692	2.746	2.800	2.856	2.914	48.595
sum incidental bank charges	1.219	1.243	1.268	1.294	1.319	1.346	1.373	1.400	1.428	1.457	24.297
sum miscellaneous operating costs	12.190	12.434	12.682	12.936	13.195	13.459	13.728	14.002	14.282	14.568	242.974
COSTS	370.285	372.780	375.325	377.921	380.569	260.503	263.258	266.067	268.933	271.857	6.783.426
sum extraordinary income	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0
OPERATING RESULT	-370.285	-372.780	-375.325	-377.921	-380.569	-260.503	-263.258	-266.067	-268.933	-271.857	-6.783.426
sum interest (6 %)	73.660	58.928	44.196	29.464	14.732	-0	0	0	0	0	1.767.840
FINANCIAL RESULTS	73.660	58.928	44.196	29.464	14.732	-0	0	0	0	0	1.767.840
PROFIT BEFORE TAX	-443.945	-431.708	-419.521	-407.385	-395.301	-260.503	-263.258	-266.067	-268.933	-271.857	-8.551.266
sum tax burdon (country specific)	0	0	0	0	0	0	0	0	0	0	0
sum tax benefits	-	-	-	-	-	-	-	-	-	-	-
SURPLUS/DEFICIT	-443.945	-431.708	-419.521	-407.385	-395.301	-260.503	-263.258	-266.067	-268.933	-271.857	-8.551.266
specific power production costs [€/kWh]	-0,139	-0,135	-0,131	-0,128	-0,124	-0,082	-0,082	-0,083	-0,084	-0,085	-0,134

4.2.3 Environmental Assessment

The exact assessment of the anticipated environmental impacts is beyond the possibilities of a feasibility study. For the accurate determination of impacts more than general data is needed.

Responsible planning needs to consider all limiting and contributing factors, leading to collection evaluation and interpretation of the data in an explicit Environmental Impact Assessment (EIA) according to acknowledged standards. For the EIA on-site inspections, measuring and monitoring are highly important.

During evaluation and visits no clear decision concerning the final site has been made. Even on repeated request in December 2005 the planning committee did not bring out a final decision. The following data and conclusions are based on the data available from the visit in December 2005 and the additional material provided.

Figure 4-15: Masterplan for the development of Cua Can and the Northwest of Phu Quoc

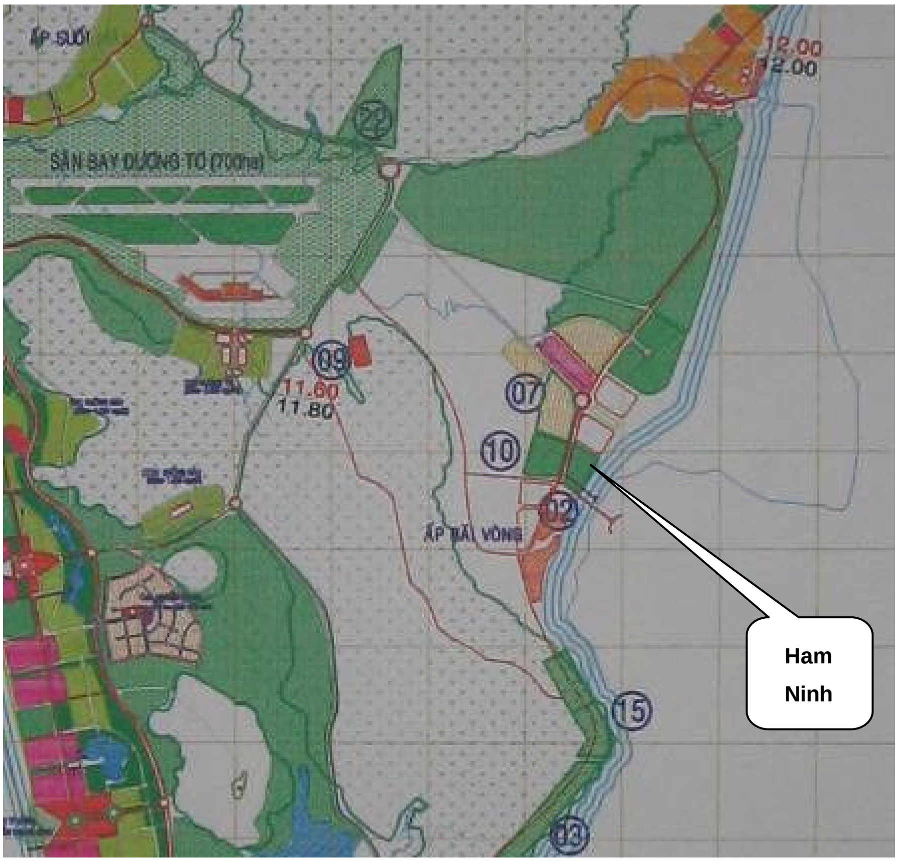


Figure 4-16: Masterplan for the development of Ham Ninh and the Centre of Phu Quoc

4.2.3.1 Local Impact

The two maps of the Masterplan (see Figure 4-15 resp. Figure 4-16) and the personal information from the meetings and field trip show that the plans go towards locating the plants as far as 3km away from settlements to avoid disturbances. Considering the need of poor people such as so called "waste pickers" to use recyclable wastes for survival and their willingness to live close to these facilities in informal settlements, measures such as fencing have to be taken. However, distances of 300 m are more realistic which by the way correspond with European standards. Thus, disturbances of formal settlements can be screened out. Informal settlements are hard to predict and should therefore not determine in initial planning but measures such as the mentioned fencing need to be considered.

The following sub-chapters briefly evaluate the impacts of solid-state fermentation in consideration of the given environmental factors such as climate, social and cultural habits, waste generation and composition on a local scale.

4.2.3.1.1 Waste – considerable positive impact

One important benefit of the biogas production plant is the significant improvement of local environmental conditions by pre-treatment and reducing the amount of organic household waste. The reduction of unmanaged and informal dumping areas will increase the number of recreational areas and subsequently help promoting the development of the desired eco-tourism on the island by minimizing the impact of waste generation on the island and preserving the natural environment.

4.2.3.1.2 Air – no impact

Potential positive impacts caused by the project implementation are based on the replacement of fossil fuel, leading to a reduction of local air pollution. On the other side, the biogas plant and maintenance might also contribute to the increasing of local traffic (transport to/from biogas combustion facility). Important in this context is the contribution towards the use of renewable energies and the local contribution in CO_2 minimization in electricity generation on a local scale.

4.2.3.1.3 Soil – considerable positive impact

The pre-treatment of household waste will supplement the high demand of organic fertilizers required by the intensive agricultural activities on the Phu Quoc Island, Vietnam. Besides livestock manure, a great amount of conventional mineral fertilizer is used to cover the demand of pepper, fruit trees and vegetable plantations. Intensive agriculture also leads to erosion which can be prevented by using the humificated substrate from the solid-state fermenter as fertilizing top-layer in the plantations.

Additionally the amount of leachate from informal tips and landfills will be prevented penetrating the soil transporting hazardous substances and depositing them in the soil-structure due to the minimized quantity of organic waste.

4.2.3.1.4 Water – positive impact

The leachate generation from informal and badly designed, managed and maintained waste treatment systems (e.g. landfills) will decrease significantly with the installation of the solid-state fermentation based biogas production system. Combined with a controlled leachate collection and treatment the water quality within the region will increase due to the minimized washout, because of the separation of organic matter, in the formal and informal landfills. This leads to the protection of rivers and vulnerable ground water aquifers.

Securing safe drinking water access also contributes to fulfil the demands 7th UN Millennium Development Goal “Ensure Environmental Sustainability”[36].

4.2.3.1.5 Noise – no impact

The local use of gas generators instead of diesel engines will lead to a general noise reduction for power generation. Nevertheless, the noise caused by transportation and collection of substrates needs to be monitored. Besides that the noise generated during maintenance of the plant needs to be assessed as well.

The overall noise exposure for the neighbours can be neglected because of the planned distances of 500-3000m to the closest formal settlements. However, factors such as noise-carrying winds have to be taken into consideration. For exact assessment long term noise monitoring or extensive noise prediction are needed.

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36 http://www.un.org/millenniumgoals/# (Accessed: 03.01.2007)

4.2.3.1.6 Odour – positive impact

Currently the unmanaged informal landfills and disposal sites cause frequent odorous impact throughout the region. Collection and adequate handling as appropriate mitigation measure of these unpleasant side effects of bad waste handling practice will limit the odour and increase the working conditions on-site such as the living conditions in the region. The solid-state fermentation prevents odours by sealed fermenters. The odour generating gas is used for power generation. Little odour will be generated by handling the wastes.

An impact for neighbouring communities is not likely to be expected because of the planned distances.

4.2.3.2 Global Impact

By using renewable instead of finite resources biogas and here solid-state fermentation promote the aim of the Kyoto protocol. Unused energy resources get used and the released carbon stays in a steady cycle or gets bound.

The most important positive global effects of biogas use are discussed in the following sub-chapters.

4.2.3.2.1 Deforestation

According to GTZ[37] biogas plants are able to replace a part up to the entire consumption of firewood or/and charcoal of an individual household in rural areas. They conclude that it is not easy to calculate the effect of introduction of a biogas plant on the deforestation due to the following assumptions [GTZ Biogas Digest]:

- In rural areas, primarily dry wood is collected first before living trees get used. Living wood gets only used when no dry wood is available.
- The firewood is usually not harvested hectare by hectare; first the dry branches, then the dry twigs, followed by smaller trees.

In most areas natural regeneration is able to carry the local demands of fire wood without getting exploited and cutting across the carrying capacity. Therefore the significance of the environmental impact caused by the reduced firewood consumption due to the introduction of a biogas facility will be relatively small. However, deforestation plays an important role for soil protection and it needs to be taken into consideration in long-term decision making processes at national or regional level.

Above that the replacement of fossil fuels and firewood by biogas avoids additional CO_2-emissions including a saving of forest resources which are a natural carbon-sink. GTZ states in this context that all these effects can avoid approximately 420 Mil Mg of CO_2-equivalents annually [GTZ Biogas Digest].

37 German „Gesellschaft für technische Zusammenarbeit"

Table 4-11: CO_2-Reduction through biogas utilization, saving of fossil fuels and firewood resources

		CO_2 Reduction [Mio t/a]
CH_4	13.24 Mio t/year CO_2-equivalent: methane x 25	330.9
Biogas	33,321 m^3/year	
Substitution of fossil fuels		44.7-52.7
Firewood savings		4.17-73.8
Total		388 – 449 (= 418.5)

[Source: GTZ BIOGAS DIGEST]

4.2.3.2.2 CO_2-Saving Potential

Reduction of greenhouse emissions by methane capture and use.

Greenhouse effect is caused by gas emissions to the atmosphere which allow the sun's short wave radiation to reach the earth surface while adsorbing, to a large degree, the long wave heat radiation from earth's surface and atmosphere. The "greenhouse gases" (gases influencing the greenhouse effect) are: water vapours (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). The increase of the greenhouse gases leads to rising temperatures. An instrument for lowering the greenhouse effect is the reduction of CO_2-emissions. Besides CO_2 the presence of other greenhouse-gases (e.g. CH_4) also contributes to global warming. Theses gases generally exist in significantly smaller quantities, but hold an outranking global warming potential. Methane contributes with 20% to the greenhouse effect (while CO_2 = 62%) but it has a 25 times higher global warming potential compared with CO_2 [GTZ Biogas Digest].

Each ton of methane that is beneficially used is equivalent to 25 Mg of carbon dioxide as contribution to the greenhouse effect. That shows the urgent need and the high benefits for sustainability of controlled biogas generation and collection generated from household wastes.

Table 4-12: Relative climatic change potential caused through different greenhouse gases within a period of 100 years after the emission, data mass equivalent of CO_2

	Relative global warming potential	
Gas	**20 years after emission**	**100 years after emission**
CH_4	63	24.5
N_2O	270	320
$FCKW_{12}$	n.	8,500
CF_3Br (Halon 1301)		5,600
C_2F_6 (Perflourethan)		12,500

[Source: ENQUETE-COMISSION (1992)]

On the worldwide scale, from the 30 million tons of methane emissions per year produced by solid waste storage, anaerobic lagoons, liquid/slurry storage, pasture etc. (animal waste management systems), almost half of the emissions can be reduced through anaerobic treatment in biogas plants.[38]

Eastern Europe, Asia and Far East contribute with the highest annual CH_4 amounts (6.2 million tons methane emissions per year each) which shows the high potential for biogas use in these regions.

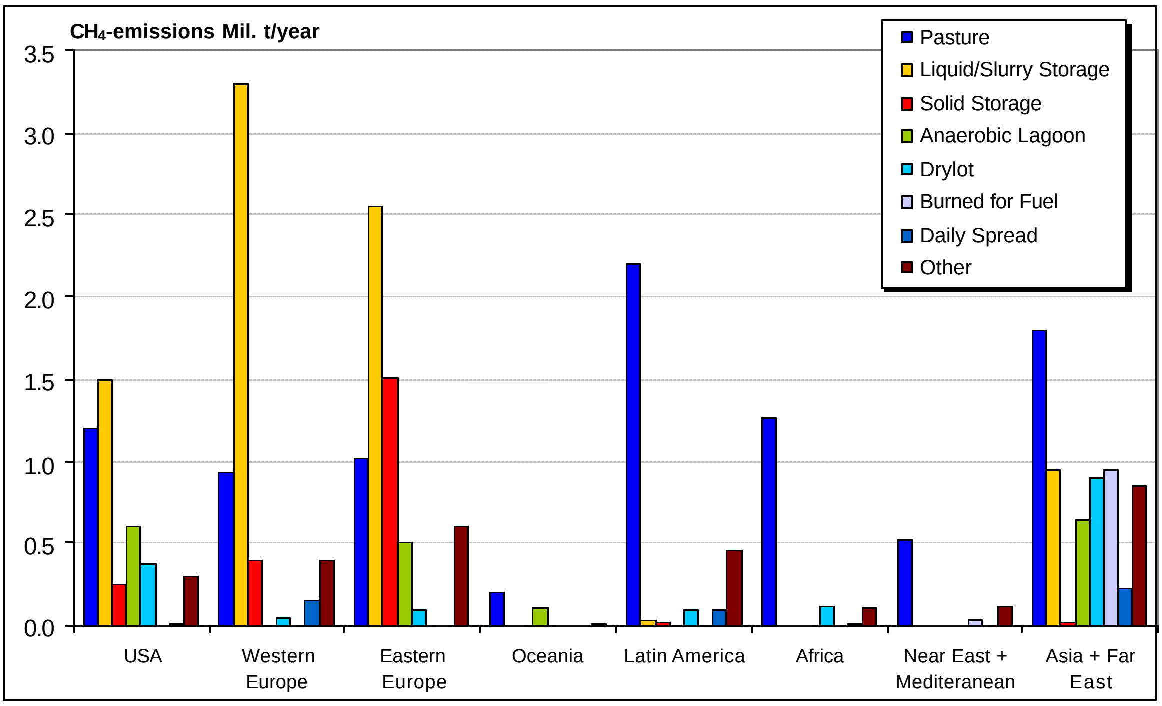

Figure 4-17: Methane emissions from different animal waste management systems[39]

Reduction of nitrous oxide emissions

Compared with CO_2 the relative per kg climate change potential of Nitrous oxide (N_2O) is 320 times higher [GTZ Biogas Digest]. Therefore, nitrous oxide is subject in regulations focusing on reduction of greenhouse gases such as the Kyoto Protocol. Besides carbon dioxide and methane, nitrous oxide is the third most important gas that contributes to global warming.

Nitrous oxide generation is a natural microbial process. It is produced during high nitrification and denitrification processes in soils, stables and animal waste management. In general, nitrous oxides emissions appear in soils without anthropogenic influence. Most of N_2O production is part of the nitrogen cycle through nitrification and denitrification of the organic nitrogen in livestock manure and animal urine. The production depends on the composition of the manure and urine and type of bacteria involved in the process, and the amount of oxygen and liquid in the manure system [GTZ Biogas Digest].

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[38] GTZ Biogas Digest

[39] CASSADA M.E., SAFLEY L.M.JR., 1990: "Global Methane Emissions from Livestock and Poultry Manure". EPA CX-816200-010

N_2O is also a product that occurs between nitrogen and oxygen during fossil fuel combustion (coal, petroleum and natural gas). The volume emitted varies with the fuel type and technology used. Replacing the diesel powered electricity generation by biogas generation the N_2O output will decrease and fossil fuel deposits can be conserved. Moreover, the project has a positive impact to the environment by reductions in acid rains caused by smog and gases that result from activities using and combusting fossil fuels.

The table below shows the estimated CO_2 reduction resulting from the construction of a biogas plant on the Phu Quoc Island, Vietnam contributing the global carbon cycle:

Table 4-13: Determination of the global environmental impacts caused by the project [Source: BiWaRE]

Climate relevant impacts caused by the baseline for energy production	6,067	t CO_2-equiv./a
Climate relevant impacts caused by the baseline for substrate disposal	20,051	t CO_2-equiv./a
Climate relevant impacts caused by the project	6,510	t CO_2-equiv./a
Project's overall reduction in climate relevant impacts	19,608	t CO_2-equiv./a

4.2.3.2.3 Potential Applicability as CDM Project

In future it may be possible to generate additional income with RE by Clean Development Mechanism. Some estimations expect prices of 3-6 \$/tCO_2equivalent (*CD4CDM*)[40]. Energy production from biomass or biogas has rather low costs for CO_2 reduction and therefore it may be a competitive solution for CDM.[41] But because of the expected rather low price, unclear framework conditions, the need for control and certain transaction costs it seems currently CDM will be an option only for big projects. Conditions for CDM may change quickly; it is worth observing the actual situation.

4.2.3.3 Summary of the Ecological Assessment

The ecological and environmental contribution of implementing solid-state fermentation with combined biogas power generation is very beneficial for Phu Quoc Island. The solid-state fermentation explains itself because of the high organic waste content and thus the high potential for biogas generation. Chapter 4.2.3 shows that the positive local impacts outweigh the negative by far. The same beneficial situation can be seen on bigger scale due to GHG[42] reduction and independent power generation (regional, national, global).

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[40] Emission trading takes also place at the European Energy Exchange see: http://www.eex.de/index_e.asp (current price 8.72 €)

[41] Tuan and Nguyen 2002, in BiWaRE

[42] Green house gas

4.2.4 Regulatory and Permitting Requirements

As already explained in Chapter 3.2 before, different legal requirements have to be met according to national standards and actual laws. The following chapters give information about the legislation and decrees specifically for the installation of the proposed solid-state fermentation based biogas facility with power generation.

4.2.4.1 Compliance with the Regulations

For clear separation of responsibilities and overview reasons this chapter is divided into “Building Regulations”, “Environmental Regulations” and “Operational Safety Regulations”.

4.2.4.1.1 Building Regulations

In Vietnam, the law in construction is a collection of documents that is promulgated by the government to adjust the issues in economy, social sector, technology and art that arise from and during a construction process (included new buildings, reconstructions, repairs), as well as basic construction fi elds (industry, infrastructure) and civil constructions (the house).

This law shall apply to domestic organizations and individuals as well as foreign organizations and individuals investing into constructions and engaging in construction activities within the territory of the Socialist Republic of Vietnam. Is an international treaty signed or acceded by the Socialist Republic of Vietnam to contain provisions which are different from those in this law, the provisions of such international treaty shall apply.

In addition, during the investment and construction process the investor, tender and constructor has to follow the obligations issued in these regulations:

Table 4-14: Building and Construction Regulations for biogas facilities in Vietnam

No.	Name of document - date of issuance - issuing authority	Contents
1	Decree No. 52/1999/ND-CP dated 8-7-1999; Decree No. 12/2000/ND- CP dated 05-5-2000 and Decree No. 07/2003/ND-CP dated 30-1-2003 - by the Government	Regulations on investment and construction management for project on Vietnam territories, include: – Conditions for starting construction of a project; – Types of projects which need to get construction license; – Competent authorities to issue construction license; – Time for issuing construction license; – Conditions and capabilities of contractors; – Written approval of bidding results and contents of contracts in necessary cases; – Procedures need to be performed after completion of the project.

No.	Name of document - date of issuance - issuing authority	Contents
2	Interministerial Circular No. 09/1999TTLT-BXD-TCDC by Ministry of Construction and Geological General Department	Concrete regulations on issuing construction license: – Who need construction license; – Construction management of the project with construction license exemption; – Background for issuing construction license; – Documents necessary for issuing construction license; – Competency for issuing construction license; – Procedures for issuing construction license and inspection of implementation; – Responsibilities of project owner on implementation progress, quality and safety of the construction project;
3	Circular No. 08/2003/TT, dated 9-7-2003 - by Ministry of Construction	Guidelines on contents and management of EPC contracts: – Requirements on preparation of Documents on requirements of the project owner; – Regulation on preparation of bidding documents; – Conditions and capability of EPC contractor; – Contract documents, contract price, payment in advance and liquidation; – Responsibilities and rights of project owner and EPC contractor in management and implementation of the contract.
4	Decision No.19/2003/QD-BXD, dated 13-7-2003 by Ministry of Construction	Concrete regulations on conditions and capability on construction activities (construction investment consultancy, installation and construction of project types): – Organization for establishment of investment-construction project: Requirement on recruitment or contract on labour, skills, degree of required positions such as project manager, leader of professional part of the project. – Project management unit: requirements on qualification, degree, experience in management for main positions (leader, deputy leader, technical head, economic head etc.). – Construction investigation contractor: requirement on number of qualified staff in terms of skills, experience for main positions such as in charge of investigation or professional areas. – Project design contractor: requirement on number of contracted labours who meet conditions on ability, professional license for project designing like this project for taking positions of project design manager and other managers as required. – Construction supervision contractor: With enough contracted labours meeting conditions on ability, degree, qualifications, experience for positions of chief supervisor and professional supervisors.

		– Contractor for reviewing quality of the project: Has enough experts for carrying out checking, reviewing quality, has standard laboratory as specified in regulation. The person in charge must have labour contract with the contractor according to requirement of laws. – Project construction and installation contractor: Has legal status, enough labours meeting requirement of project construction and installation works; has machines, equipment for construction ensuring technical, quality and safety requirements suitable to the project; has suitable quality management system, ensuring insurance related to works; has enough labours in terms of skills and qualifications for main positions such as Chief of construction and in charge of construction technique. – Main contractor: Has sufficient qualifications and experience as required; directly carrying out the main works and at least carrying out 70% works for design contractor and over 50% for construction and installation contractors. – Capabilities required for EPC contractor: Has capabilities as required for all the above mentioned contractors and has enough experience as EPC contract implementation.
	Decision No.1242/ 1998 QD-BXD, dated 25-11-1998	Issuing "unit costs for basic construction works"
	Circular No. 109/2000/TT-BTC, dated 13 -11-2000 by Ministry of Finance	Fees for investment appraisal works
	Degree No 709/QD-NLDK, dated 3/4/2004 by MOI	Guideline Draft for Economic - Financial analysis and ceiling electricity purchasing and selling price for investment project of power sources.

According to the Decree 52/1999/ND-CP all electric production projects with a total investment cost over 400 billion VND would be ranked in group A. Therefore, the project on "production of renewable energy from organic waste and biomass by biogas plants at Phu Quoc" with the estimated cost of 38.51 million € (750 billion VND) will belong to group A.

This project has to be submitted to the Prime Minister for approval. In the case where some overseas companies share the investment cost, the investors have the responsibility for the economic efficiency. Besides, the current regulations also require all project owners to submit documents on assessing the construction planning, architectural options, applied construction technology, land use, environmental protection measures, fire prevention and social aspects of the construction project to Ministry of Planning and Investment (MPI) for assessment. The result will be issued 60 days after the MPI has received all required documents.

The environmental regulations and their contents are discussed in the following chapter.

4.2.4.1.2 Environmental Regulations

Similar to the Construction Law, all projects in Vietnam have to follow all articles mentioned in the Environmental Protection Law. The regulations stated below should be referred to during preparation and implementation of the project.

Table 4-15: Environmental Regulations for biogas facilities in Vietnam (TCVN: Vietnamese standard)

No.	Name of document -date of issuance - issuing authority	Contents
1	Circular No. 55/2002/TT-BKHCNMT dated 23-7-2002 by MOSTE	– Guidelines on reviewing technologies and environmental issues of investment projects. – Regulation on the projects which have to be reviewed. – Contents to be reviewed in terms of environmental aspects: environmental polluting resources, solid, liquid, gas pollutants produced during production process etc., environmental accident risks and mitigation measures.
2	Circular No. 490/TT-BKHCNMT dated 29-4-1998 by MOSTE	Guidelines on preparation of and reviewing environmental impact assessment report for the investment projects.
3	TCVN 5949 : 1998	Regulation on maximal permissive noise level by time in day in the public and residential areas
4	TCVN 5939 : 1995	Regulation on air quality - Standards on industrial flue gas (dust and inorganic substance concentration in industrial emission discharged in industrial zones).
5	TCVN 5940 : 1995	Regulation on air quality - Standards on industrial flue gas (Organic substances in industrial emission discharged in industrial zones).
6	TCVN 6991 : 2001	Regulation on air quality - Standards on industrial flue gas - (Standards on inorganic substances in industrial emission discharged in industrial zones).
7	TCVN 6994 : 2001	Regulation on air quality - Standards on industrial flue gas - Standards on organic substances in industrial emission discharged in industrial zones.
8	TCVN 6992 : 2001	Regulation on air quality - Standards on industrial flue gas - Standards on inorganic substances in industrial emission discharged in urban zones.
9	TCVN 6993 : 2001	Regulation on air quality - Standards on industrial flue gas - Standards on inorganic substances in industrial emission discharged in rural and mountainous zones.

No.	Name of document -date of issuance - issuing authority	Contents
10	TCVN 6995 : 2001	Regulation on air quality - Standards on industrial flue gas - Standards on organic substances in industrial emission discharged in urban zones
11	TCVN 6996 : 2001	Regulation on air quality - Standards on industrial flue gas - Standards on organic substances in industrial emission discharged in rural and mountainous zones.
12	TCVN 5945 : 1995	Regulation on industrial effluents discharge - Standards
13	TCVN 6980 : 2001	Water quality - Standards for industrial effluents discharged into river used for domestic water supply.
14	TCVN 6982 : 2001	Water quality - Standards for industrial effluents discharged into river used for water sports and recreation.
15	TCVN 6983 : 2001	Water quality - Standards for industrial effluents discharged into lakes used for water sports and recreation.
16	TCVN 6984 : 2001	Water quality - Standards for industrial effluents discharged into river used for protection of aquatic life.
17	TCVN 6985 : 2001	Water quality - Standards for industrial effluents discharged into lakes used for protection of aquatic life.
18	TCVN 6986 : 2001	Water quality - Standards for industrial effluents discharged into coastal waters used for protection of aquatic life.
19	TCVN 7440 : 2005	Standards on emissions in electric power industry
20	Decision No.07/2005/QD-BTNMT dated 20-9-2005	Decision an application of Vietnam standard TCVN 7440 : 2005 – Standards on emission in thermal power industry

4.2.4.1.3 Operational Safety Regulations

The responsibility for production, distribution, and sale of electricity on Phu Quoc lies with the Electric Power Company 2 in Kien Giang province, regional subsidiary of the national state-owned utility Electricity of Vietnam (EVN). The initiative to complement the island's electricity system with renewable energy technologies was received well by the Electric Power Company 2.

In general, the operational safety regulations for power generation are mentioned in the following documents.

Table 4-16: *Operational Safety Regulations for biogas facilities in Vietnam*

No.	Name of document - date of issuance - issuing authority	Contents
	Regulations on safety for electrical equipment of power plants and power network- ministry of Electricity - 1984. (Volume I: equipment of power plants and substations) - issued together with Decision No.25DL/KT dated 22-01-1985 by Ministry of Electricity.	– General requirements for persons who directly work on management, operation of electric equipment in power plants and substations with voltage up to 1000 V and above 1000 V (heath, qualifications, trained, periodical check and ranked on technical degrees on technical safety). – Regulation on rights and duties for persons who are responsible for safety; – Principles of operation; – Equipment, tools used when carrying out works on or in contact with electric equipment. – Measures for ensuring safe works; – Regulation on awards and fines related to implementation of technical safety standards.
	Decision No.235 QD/LD by MOLISA & State Techn.Committe.	Decision on technical safety for steam boilers.
	Regulation on safety of steam boilers (QPVN 23-81) dated 05-9-1981.	Regulation on safe manufacture and use of steam boilers, including: – Regulations on installation of steam boiler for safe operation – Technical inspection for steam boiler and its parts which are newly installed; – Periodical inspection and hydraulic testing for steam boilers in operation (one time every two years); – Sudden inspection: for steam boiler after one year operation stop; moved to other place after repairing etc. – Regulation on qualifications of technical staff.
	Decree No. 06/CP dated 20/01/1995	Some clauses of Labour Law on labour safety, labour hygiene.
	Decree No. 110/2002/ND-CP dated 27/12/2002 by the Government	Amendments of some clauses in the Decree No. 06/CP by the Government.
	Circular No. 23/2003/TT-BLDTBXH dated 03/11/2003 by Ministry of Labour, Social and Invalid Affairs	Regulation on list of equipment and substances related to labour safety, which must be strictly checked and registered (steam boilers with pressure over 0.7kg/cm^2, water heaters with liquid temperature over 115 oC etc.)

No.	Name of document - date of issuance - issuing authority	Contents
	Interministrial Circular No. 03/2003/TT-BTC dated 10/1/2003 by Ministry of Finance	Schedule on fee levels for inspection, testing technical safety for machinery and equipment.
	Electricity law endorsed by the National Assembly on 03-12-2004	The definitions on electricity operations: Obligations of electricity generators in complying with the procedures, standards on operation of power plants, power networks, finding measures for treatment of faults causing unsafe conditions for lives. Regulations on safety in power generation: arrangement of power plants, equipment necessary for prevention of fire, explosion, emergency exit system, lighting system, danger warnings etc.
	The Decree No. 105/2005/ND-CP dated 17 /8 /2005 by the Government	Guidelines on implementation of some clauses of Electricity Law: Requirements for handing over design, technical documents and implementation of testing, commissioning before operation of the project. Requirements on qualifications for individuals whose works are directly related to electricity; Entrusting of duties on electric safety to: Ministry of Industry, Ministry of Science and Technology, Ministry of Construction, People Committees of provinces, cities under management of the Government. Regulation on safety for power transmission (substations, overhead lines and underground cable lines etc.).

Besides the regulations for construction and maintenance of renewable energy power plants different obligations for investment.

4.2.4.2 Obligations to Obtain Permissions

For permission two stages of permission are required the national permission to conduct a project in Vietnam and the permission to invest in Vietnam and to operate business. These two kinds of permission and its obligations are discussed in this chapter.

4.2.4.2.1 National Permissions

In order to invest and construct a biogas power plant on Phu Quoc Island it needs permits from competent authorities.

Vietnam Government issued the Decree No. 52/1999/ND-CP dated 8-July-1999 promulgating regulation on investment and construction of a project on Vietnam territories. The Decrees No. 12/2000/ND-CP dated 05-5-2000, decree No. 07/2003/ND-CP dated 30-1-2003 specifying some amendments for Decree No. 52/1999/ND-CP. Besides, related ministries and sectors issued circulars guiding for implementation of these decrees.

<u>According to the regulation, procedures for investment and construction of projects in Vietnam are as follows:</u>

I. Investment preparation,

II. Investment implementation, and

III. Investment finishing, putting the project into operation.

<u>The investment projects are divided into two main types:</u>

I. Projects using domestic financial capital resources (including foreign loan by the government and ODA) and projects with foreign investment capital.

II. Projects using domestic financial capital resources are divided into 3 groups (A, B and C). Investment levels of projects in groups A, B, C for each production and business categories are various. For projects producing energy (electricity), limits of investment amounts for groups A, B and C are above 600 billion VND, 30-600 billion VND and up to 30 billion VND respectively (equivalent to above) 37,974,000, 1,898,000-37,974,000 and up to 1,898,000 US$.

4.2.4.2.2 Procedure to Get Investment Permission

According to Decree 52/1999/ND-CP of the government, all electric production projects with the total investment cost over 400 billion VND would be ranked in group A. Therefore, the project on “production of renewable energy from organic waste and biomass by biogas plants at Phu Quoc” with the estimated costs of 38.51 million € (≈ 750 billion VND) belongs to group A. This project has to be submitted to the Prime Minister for approval. In case of cost-sharing (investment cost) by some overseas companies, the investors have responsibility of economic efficiency. Besides that, the current regulations require all project owners submitting the documents on regarding construction planning, architecture option, applied construction technology, land use, environmental protection measures, fire prevention and social aspects of the construction project to Ministry of Planning and Investment (MPI) for assessing. The result will be issued 60 days after MPI receiving all required documents.

During the investment and construction process the investor, tender and constructor has to follow the so called ‘Clause 4’.

Clause 4: Investment and construction procedures

1. Process of investment and Construction includes 3 phases

I) Phase of Investment Preparation

II) Phase of Investment Implementation

III) Phase of Construction Accomplishment, putting the work into operation

2. All the tasks of investment and construction implementation stage could be processed in sequence, overlap or intermixing according to the project's specific conditions and the decisions of investor.

3. Investor has responsibility to recover capital and pay back investment capital.

<u>In phase of Investment preparation, there are 3 important steps:</u>

I. Writing project investment proposal,

II. Appraising project and Submitting documents for approval,

III. Project assessment and project investment Decree.

I. <u>Writing project investment proposal</u>

The basic study documents of investment project include pre-feasibility study report, feasibility study report and investment report.

For projects of group B, pre-feasibility report must be prepared only in case competent body for making decision on investment has written request on this report. The projects of group C with investment capital above 1 billion VND (63291 US$) need to prepare feasibility report, investment report. For the projects with investment capital less than 1 billion VND, only investment report is needed.

II. <u>Appraising project and Submitting investment acceptance for Prime Minister's approval</u>

For projects of group A, the pre-feasibility need to be prepared for getting investment license (except those which have been decided for investment by the National Assembly or the government or the project is a component of the bigger project which has pre-feasibility report already approved).

The submitted document for Prime Minister's approval in pre-feasibility study report and investment acceptance contents:

+ Submitted paper for Prime Minister's approval attaches with pre-feasibility study report and investment acceptance Report of Investor.

+ Documents that confirmed legal entity of investor –

+ Plan of project capital mobilizing -

+ Legal documents that related to project site and another legal papers.

III. Project assessment and project investment Decree

Documents of investing appraisement includes:

+ Statement paper of investor applies to investing certificate jurisdiction office (regulated in laws), attaching with final project feasibility report.
+ Project verifying documents and submitted report of investigating office to Prime Minister for investing certification
+ Prime Minister's Investing Acceptance Documents
+ Investigating suggestion of loan banking organization about financial plan, pay back plan, loan acceptance (to project using loan capital)
+ Documents and updated data of compensation, site clearance, resettle plan (in which project had requires for resettling)

The content of Investment Decree includes:

1. Investment Objective
2. Investor Declaration
3. Project Management Form
4. Location: land use area, environmental protection approach, resettle and recover plan (if any)
5. Technology, designed capacity, architecture approach, technical standard and construction level
6. Regulation of national resource exploiting and utilizing (if any)
7. Total investment capacity -
8. Investment resource, financial capacity and capital plan of project
9. Project's Subsidization, Supports from government
10. Project implementation approach. Regulation of bidding package division and the way of contractor selection.
11. Construction time and principal progress stones. Latest time for commencement and completion
12. Relationship and responsibility of relative Ministry, local government (if any). Effective date.

IV. Phase of investment implementation

In this phase, some important content related to certification are: application for land distribution or renting, construction certificate, resource exploitation certificate (if any), appraisement of approved design and total construction estimation, selection of consultative contractor, purchase of equipment and construction material.

During project implementation, if the project is managed directly by the investor manages the Project Management Board has to apply for legal entity. If investor rents another professional organization to manage the project, this candidate has to register for certificate of investment and constructing consultant.

V. Phase of Construction Accomplishment and Construction Operation

After completion of construction work, the commissioning and taking over the project must be carried out, the total cost of the project must be liquidated and the project must be registered as the owner's asset according to the laws.

According to Master Plan approved by the Minister on November 11th 2005, Phu Quoc Island has many advantages in regard to the considered investment and construction. The Project on "Production of Renewable Energy from Organic Waste and Biomass by biogas Plants at Phu Quoc Island" will create many benefits on tourism and subsequently social - economic issues. Because of the economical advantages for the region it was strongly supported by local government at Provincial and District level.

Following the national electricity regulations for feeding power to the regional grid operated by the state owned Electricity of Vietnam (EVN), the investors have to get an agreement with the operator. Before permission, the plant-operator needs to discuss the issues with the Kien Giang's People Committee, Phu Quoc's People Committee and EVN. In November 2005, group of project's experts presented the projects and discussed mitigation and measures with the stakeholders. At the end of the participatory meetings the project got appreciated in consensus of all stakeholders.

4.2.4.3 Summary of the Legislative Assessment

The legislation affecting the construction and operation of the anticipated project is basically determined by the regulations and laws concerning buildings and construction requirements, environment and operational safety. These requirements apply to local as well as international or foreign organisations.

An important point in the building regulations is that qualified staff is required for construction and the main contractor has to have experience and qualification to carry out the work, which tries to ensure building standards and guarantees that cannot be ensured by untrained workers from the informal economy.

Besides the general permissions given by laws and regulations the projects are separated by its investment volume in classes A, B and C and need to be approved by the Prime Minister. Above that all project owners need to submit detailed planning documents to the Ministry of Planning and Investment for assessment. Projects of group A need a pre-feasibility study handed in at the Prime Ministers Office for getting the investment license.

Environmental regulations have high emphasis on water and air quality. Besides that the operational safety gets also regulated by different laws and decrees reaching from technical safety over labour safety to definitions on electricity operations.

Generally the implementation and the legislative situation as well as the ministerial support of the anticipated project can be seen as very promising because of its consideration as group A project and the Master Plan of November 11th 2005 to develop Phu Quoc Island towards renewable energy use.

4.2.5 Social Impact Assessment

The assessment of the social impact of waste management combined with power and job generation is a complex topic to discuss. Phu Quoc Island's socio-economic conditions such as different economical, social and cultural issues and some anticipated outcomes are already discussed in depth within Chapter 2. Therefore this chapter focuses on the system specific social effects of introducing a solid-state fermenting based biogas production with power generation.

The following sub-chapters discuss the effect on the general employment situation and the safety at work.

4.2.5.1 Employment

One important advantage of solid-state fermentation and energy-generation from biomass is its employment generation. Based on a dutch study it is estimated that energy generation from biomass generate twice as much of employment compared to energy generation from coal.[43] Regarding the fact that labour in Asian countries is usually cheaper than in Europe it can be expected that employment generation will be even higher. A general analysis about bioenergy based on data from Latin America and Southeast Asia comes to the conclusion that employment up to 800 person years/PJ or income up to 700,000 $/PJ can be generated.[44] Additionally to these directly generated jobs indirect employment generation can be added (e.g. trade with goods from pre-selection).

It is also estimated that needed investment per job is much lower in biomass energy industries than in other branches. This means with the same amount of money more employment can be generated than in other sectors. So especially in regions with high unemployment, energy from biomass can create more easily jobs than investment in other sectors or convert informal jobs such as 'waste pickers' into formal jobs 'waste collectors'

This kind of investment brings employment not only to well educated people like engineers. For the handling of biomass also some unskilled labour is needed. This is very important for the 'waste pickers' which nowadays have their income from collecting and make further use of the collected wastes. These people could lose their income when separating the wastes and using them most efficiently. Therefore it is most important to take these weak social classes into consideration and give them appropriate solutions to maintain their living such as waste collection and separation for money.

[43] Bhattacharya 2001 in BiWaRE

[44] IEA Bioenergy 2003, in BiWaRE

Energy production from biomass in rural areas brings additional advantages. It can generate some additional income (for the owner and for the employees) and make this areas more attractive for further investment (e.g. due to stable power grids). D. Nianguo Li (Biogas production in China: an overview[45] mentions a case where village income doubled within two years (not only, but also because of biogas introduction).

Renewable energy from biomass can make agriculture more attractive and work against urbanisation by strengthen the rural areas with job generation, which is a huge problem in all fast developing countries. Any income generation in rural areas and any promotion of farming should be welcomed. The money which is paid for the electrical energy from consumers comes directly back to the region (e.g. farming for biomass or food production). Energy production in big power plants transfers the money only into the areas with power plants without strengthen local economy (or abroad to pay for the fuel).

Biomass use in rural areas is able to diversify the economic structure. It gives better regional stability against economic disruption. Electricity demand and electricity price will be more stable and change less than other economic indicators and prices. Farmers who sell their biomass are also less vulnerable to crop failures or declining crop prices.

4.2.5.2 Health and Safety at Work

While processing solid state fermentation needs only little turning and maintenance conducted by hand, therefore the safety for workers during the process can be considered as very high. Possible source for injuries is the trash removal during pre-separation.

For workplace safety the workers need to be equipped with adequate personal safety gear according to European standards such as:

+ gloves
+ overalls
+ protective shoes
+ etc.

The equipment provided needs to be cleaned periodically to avoid health threats from untreated waste, residing bacteria and fungi. During waste-handling inhalation protection must be used to prevent pulmonary diseases.

Additionally mandatory specific safety training for the facility staff should be conducted periodically and also the collector should be given a basic training for safety awareness. Besides that they also should be equipped with personal protective gear and tools for collection (e.g. bags).

[45] DaSilva E. J. et al 1987 in BiWaRE

4.3 Option 2: Combustion Plant

The use of biomass for the production of heat and energy in developing countries has to deal with very special regional particularities. A technical solution must especially consider the following parameters:

- Low investment costs at a small plant size
- Robust technology
- Easy to handle process
- Low degree of emissions without special treatment installations
- High efficiency factor
- Minimisation of waste to be landfilled

A combination of a solar drying process and a combustion plant with energy recovery by the innovative Pebble-Heater technology matches these requirements.

The solar drying raises the heat value of the input without the use of further external resources and stabilizes it biologically. A pre-sorting process stage improves working conditions and efficiency of the scavengers significantly and excludes unwanted material from the further process.

Due to the uncomplex Pebble-Heater technology, the investment is lower than for other technical solutions, an investment of 5.5 Mio € is estimated, the involvement of local firms in the building process can reduce costs further. The transport medium for the heat is air instead of water, which makes the process easier to handle and minimizes heat transfer losses.

The Pebble-Heater functions as a filter and reduces the emissions of dust, aerosols and tar by 50 % compared to other technologies.

The electrical efficiency of the Pebble-Heater technology is with up to 30% much higher than for all other technologies set into practice. The Electricity output is estimated with about 1.2 MW_{el} for an overall input of 16,000 Mg waste per year.

The solid output amounts to about 4 % of the input only, is biologically stabilized and free from smell. No wastewater is produced.

4.3.1 Process Design and Technical Assessment

In order to generate renewable energy while reducing the volume of biomass and waste, the experts of the RENEW-consortium also assessed the applicability of an innovative biomass power plant based on Pebble-Heater technology and hot air turbine. Due to the use of heated combustion air, even materials with high water content like waste from households or wet forestry residues can be used for burning which makes this technology favourable for Phu Quoc. Figure 4-18 shows the simplified flow chart of the pebble heater process.

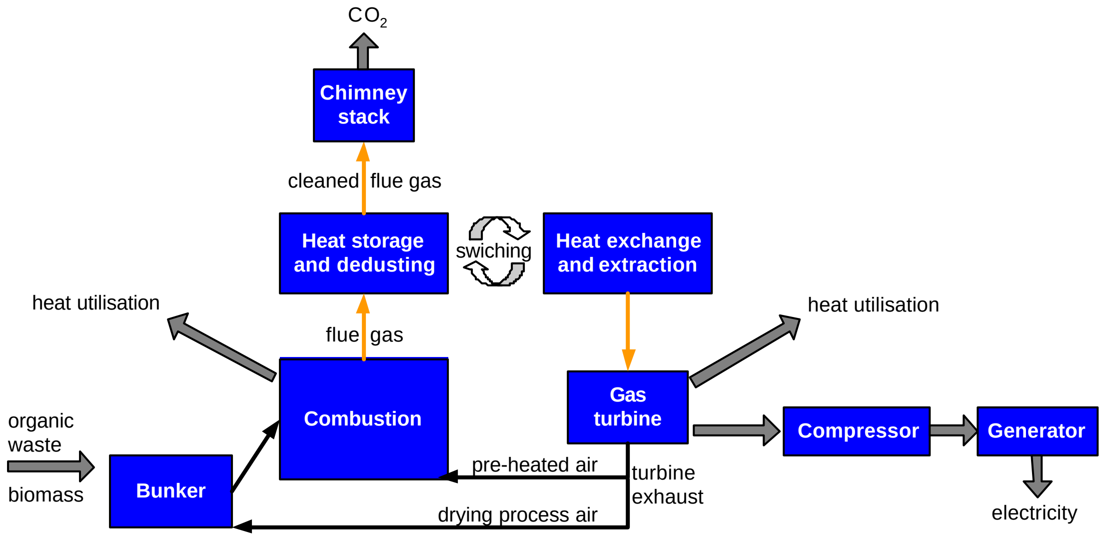


Figure 4-18: Simplified flow chart of the pebble heater process

4.3.1.1 Description of Technology

4.3.1.1.1 Components

The chosen incineration process consists of the two components

- Conditioning/storage
- Incineration/Power generation

Conditioning/storage

The waste is delivered into a flat bunker. Its advantage for the favoured solution is the possible flexible segmentation into different areas with different functions. Furthermore, the waste can be transported easily to all process steps by wheel loader.

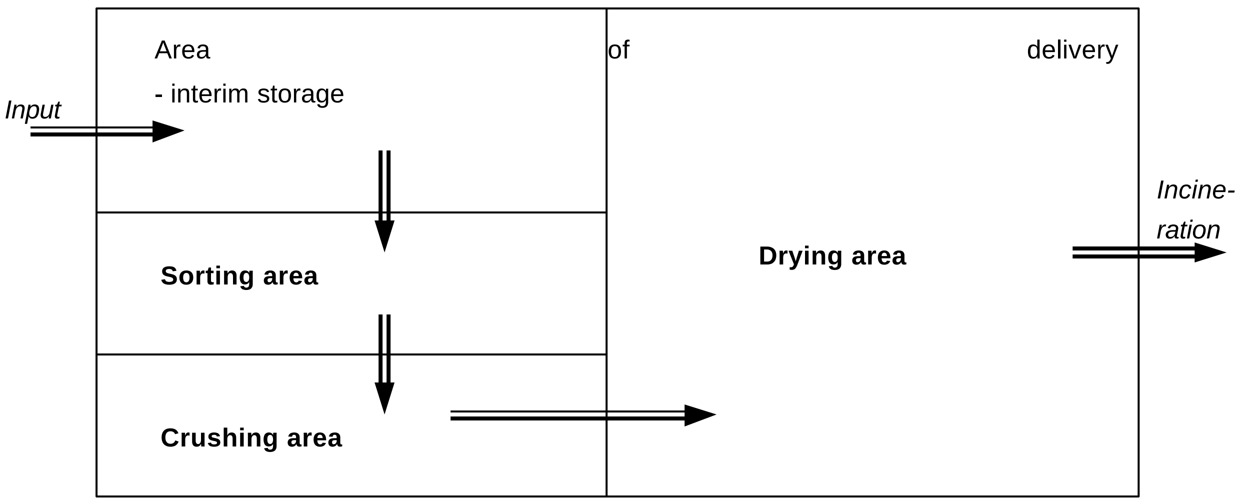


Figure 4-19: Scheme of the conditioning area

Figure 4-20: Area of delivery

To ensure a quick unloading process independent from peak-de-loading times, an interim storage is foreseen. From here, the input is transported to the sorting area, where materials have to be sorted out manually, which

- inhibits the incineration process, e.g. minerals, glas, metal
- causes problems at the crushing aggregate due to its material properties, e.g. strings
- may cause hazardous emissions in the incineration process, e.g. chlorine-containing plastics, dyes, solvants
- is a marketable material, e.g. paper, metal

Figure 4-21: Belt for manual sorting

According to the source and composition of the material, the sorting process can be adapted in short and long term without further expenses.

The following crushing process aims to reduce the size of the material pieces and to tear plastic foils/bags to improve the drying process and charging of the burning chamber.

Figure 4-22: Waste grinding machine[46]

Afterwards, the sorted material has to be transported into the drying area, where the solar drying process will take place.

The drying process bases on convection and radiation processes, initiated by the sun. On an industrial scale, it is done in halls with transparent roof, resp. transparent walls. The material is heated, which supports the evaporation of the of the water content. The air in the hall is also heated, which improves the water absorption capacity. Due to the chimney-effect, which utilizes the differences in the density in-/outside the hall, the air is transported upwards and outside. On its way through the hall, the evaporated water is transferred from the solid material into the air and transported away.

To intensify the water transport into the air and to prevent anaerobic biodegradation processes, the solid material is turned occasionally.

Alternatively, the air is pre-heated in the incineration process, before it is blown into the drying hall.

[46] HLII 1417, Husmann Zerkleinerungstechnik

Figure 4-23: Solar drying of sewage sludge[47]

The product of the conditioning process is a biologically stabilised, storable fuel with a relatively high heating value.

Besides the drying process, the drying area is also used for the storage of the fuel.

Incineration/power generation

The fuel is burnt under ambient pressure. For the foreseen cycle, a more or less standard biomass combustor may be used. Possible solutions are furnaces with classical/water-cooled grates or with conical rotational grates. Fluidized bed combustion is difficult to implement, since it requires a fuel with constant characteristics.

The main part of the combustion air is provided by the hot air exhaust from the turbine. Due to the use of heated combustion air, even materials with high water content can also be used for burning. Referring to the project, a varying water content in the fuel after the solar drying process due to variations in the delivered waste amounts or the drying efficiency can be partly compensated.

Further, the hot flue gas diluted by a high excess of the combustion air transfuse their sensible heat to a heat exchanger, the so called pebble heater. In addition to the task of heat exchanging, the pebble heater is also dedusting the hot gas. So, flue gas cleaning is not necessary if just burning waste derived fuel.

47

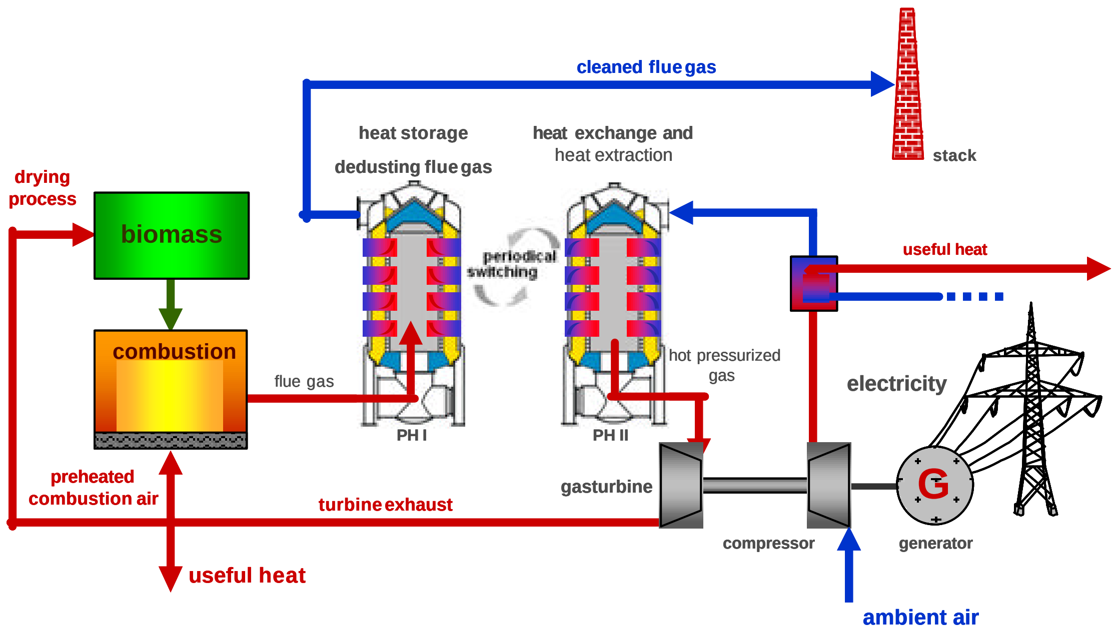


Figure 4-24: Scheme of combustion plant [Source: ATZ Entwicklungszentrum Sulzbach-Rosenberg]

At the same time, another warmed up pebble heater is pressurized by a compressor which ingests air from the ambient. By flowing through the pebble heater, the pressurized air is heated up and can be used in a gas turbine generator to produce electricity and powering the compressor.

As aforementioned, the hot air leftover by the turbine exhaust can further be used for warming up the combustion air and for drying the fuel.

The resulting ash is landfilled.

4.3.1.1.2 Substrate

There are two types of fuel foreseen for the combustion process:

- Wood produced for the single purpose to burn it producing electricity
- Processed waste with the main aims to reduce its amount and impact on the environment and to produce electricity

Type of Substrate

<u>Wood</u>

The production potential of wood on Phu Quoc is estimated with 870 Mg/year. With a share of about 7 % of the overall fuel potential only, it shall not be regarded here in depth.

In practice, it is recommended to co-combust wood, when the capacity of the plant is not charged to capacity by the RDF.

Waste

Biomass resources of Phu Quoc include 4 main groups: (i) waste from plants; (ii) residues from wood processing industry; (iii) waste from people and animals; and (iv) residential waste. The frame conditions mentioned above indicate that the substrate resource which can be collected for the generation of renewable energy by combustion plants in Phu Quoc is residential waste resource.

Residues from plants include post-harvest residues such as from sweet potatoes, cassava, vegetables and some industrial trees as well as trees from natural forests, plantation.

Table 4-17: Waste composition [Source: BiWaRE 2005]

Components	***TOTAL waste (2005)***		***Combustible Organic***	***Combustible Inorganic***	***Incom-bustible***
	(%)	*(tons)*	*(%)*	*(%)*	*(%)*
Paper	*4.37%*	*684*		*4.37%*	
Glass	*2.38%*	*373*			*2.38%*
Metal	*1.28%*	*200*			
Plastic sac	*8.05%*	*1,260*		*8.05%*	
Food waste, vegetable waste	*53.36%*	*8,354*	*53.36%*		
Garden waste	*3.08%*	*482*	*3.8%*		
Shell, hulls, peel	*10.77%*	*1,686*	*10.77%*		
Wood waste	*0.72%*	*113*	*0.72%*		
Bone, shell...	*2.55%*	*399*			*2.55%*
Ceramic waste, brick	*3.92%*	*614*			*3.92%*
Clout	*1.69%*	*265*		*1.69%*	
Shoes, sandal…	*1.54%*	*241*		*1.54%*	
Pin...	*0.01%*	*2*			*0.01%*
Other	*6.39%*	*1,000*		*6.39%*	
Total	*100.00%*	*15,656*	*67.9%*	*22.0%*	*8.9%*

The solid waste of Phu Quoc island, especially the solid waste from hotel, restaurant is similar to the household waste.

Together with socio-economic development and urbanization increase, every year Phu Quoc creates a certain amount of solid waste. However, with the slow development of industry in Phu Quoc, at present, the residential waste is a main share of solid waste at the island.

Quantity of Substrate

Waste from households

According to the previous estimations (World Bank, 2004), the amount of waste produced by one person in Vietnam is situated between 0.3 kg/(person*day) in rural areas and 0.7 kg/(person*day) in big cities. For Phu Quoc, an average of 0.5 kg waste/person/day was considered for the year 2005, with an increase up to 0.7 kg/(person*day) for 2025. This increase can be justified by the expected improvement of lifestyle conditions (increase in population's income and consumption), simultaneous with the socio-economic development of the region in the next years.

Thus, the annual rate of household waste produced by the population of Phu Quoc in 2005 can be calculated as follows (for the calculation it was also assumed a 100% collection rate of waste):

85,000 x 0.5 x 365 = 15,512,500 kg ˜ 15,512 tons (2005)

The expected waste in 2025, taking into consideration the average population growth ratio of 5.3% and the increased ratio of waste per capita and day of 0.7 kg would be:

238,700 x 0.7 x 365 = 60,987,850 kg ˜ 60,988 tons (2025)

Waste from tourists

Apart from the waste produced by local population, the tourists waste contributes significantly to the overall waste. The average stay duration of a tourist is 3-4 days (PHU QUOC DISTRICT 2004). The daily amount of waste produced by the tourists is considered to be about 1.2 kg/(person*day), ca. double than local residents (WORLD BANK, 2004) and thus the yearly estimated rates:

Waste produced by tourists in 2005:

220,000 x 1.2 x 4 = 1,056,000 kg ˜ 1,056 tons (2005)

Waste produced by tourists in 2025:

500,000 x 2.0 x 4 = 4,000,000 kg ˜ 4,000 tons (2025)

The total amount of waste produced on Phu Quoc Island from local population and tourists is:

- 2005: about 16,568 tons
- 2025: about 64,988 tons

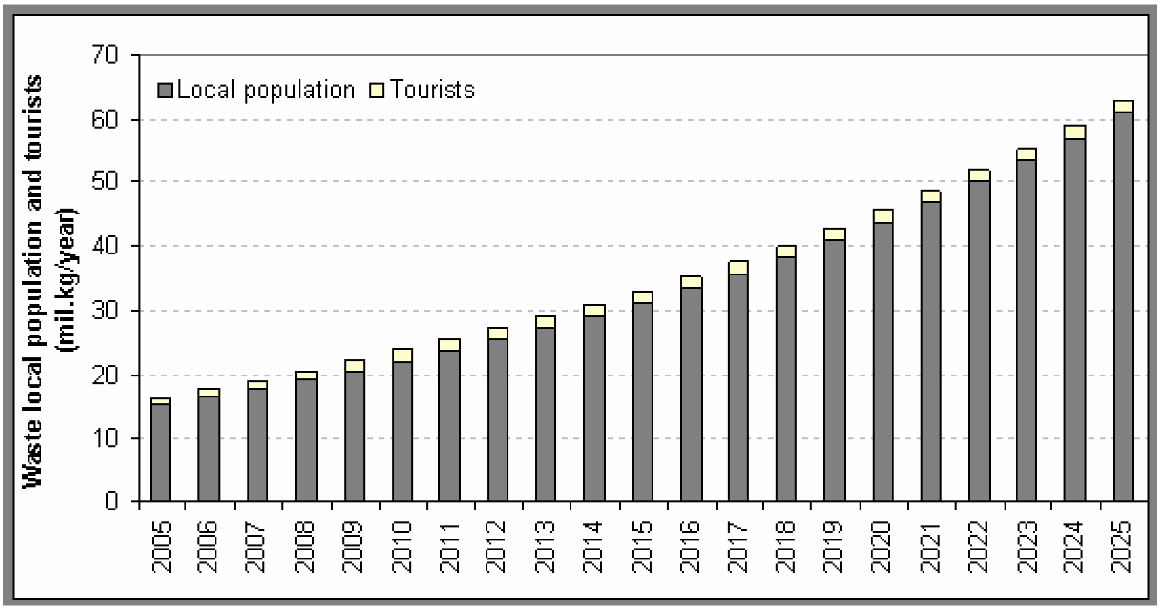


Figure 4-25: Estimation of total waste production for 2005 – 2025 (local population and tourists)

<u>Waste from seasonal workers</u>

Due to difficulties in the estimation of the number of seasonal workers from construction, fishery, agriculture and other branches, the total amount of waste produced on the Phu Quoc island was evaluated to increase by 5%. The estimation is very general and the final number may vary due to the climatic changes and economical perspectives.

The total amount of household waste, including the waste produced by the seasonal workers is:

- for 2005: 16,568 tons x 1.05 = 17,396 tons
- for 2025: 64,988 tons x 1.05 = 68,237 tons

<u>Waste from animals</u>

The source of wastes from animals includes mainly from excrements of animals such as pigs, buffaloes, cows, and poultry. As of the end of 2004, Phu Quoc has about 15,000 pigs, 2,900 cows and 100,000 fowls. Total potential of this resource is assessed as follows:

Table 4-18: Source of animal excrement for production of RENEWable energy in Phu Quoc (2004) [48][1]

Source	Quantity (animals)	Waste amount (tons/year)
Pigs	15,000	14,235
Cows	2,900	18,524
Fowls	100,000	912.5

Among the waste sources from animals mentioned above, only waste from pigs is highly concentrated. It may be found in the households having large scales of husbandry, however, maximum only 15-20 tons of substrate per year.

[48] Assessment by study team - IE

Recently, these amounts are used for the own or neighbouring crop farming. Most of the small scale farmers have no collection facilities, yet. Thus, a suitable system of collection and transport would have to be implemented as a pre-condition for using this kind of substrate economically.

Due to the relatively high heat value of about 15 MJ/kg and the high annual amounts, this type of waste is interesting to use as a fuel. Hygienic aspects in the conditioning process prevent the use as a fuel so far.

According to the report of the Public Project Management Board and Department of Natural Resources and Environment of Phu Quoc district, the amount of waste which can be collected in recent years is increased as reflected in Table 4-19. The collected waste amounts mainly from residential areas such as two towns Duong Dong, An Thoi and Ham Ninh commune.

Table 4-19: Total quantity of solid waste generated and collected from 2001 to 2004[49]

Year	Total quantity of solid waste (ton) [estimation number]	Total quantity of solid waste collected (ton)	Collection ratio (%)
2001	13728	5886	42.9
2002	14086	7200	51.1
2003	15170	8972	59.1
2004	15210	13080	86.0

According to the forecast of the Phu Quoc island Environment Resource - Traffic - Construction Department, the quantity of waste will increase on the average of 3000 tons per year during 2005 - 2010.

The estimation is mainly based on the population growth and number of tourists as follows:

+ In 2005, Phu Quoc had 88,304 residents and 220,000 tourists with an average stay of 3 days having a solid waste generation rate of 0.5 kg waste/person*day. Therefore, the total quantity of solid waste generated in 2005 is:

  $(0.5 \times 88,304 \times 365) + (0.5 \times 220,000 \text{ x } 3) = 16,445,000$ kg = 16,445 tons

+ In 2010, Phu Quoc will have 120,700 residents and 500,000 tourists with an average stay of 4 days having a solid waste generation rate of 0.7 kg waste/(person*day). Therefore, the total quantity of solid waste generated in 2010 can be estimated as following:

  $(0.7 \times 120,700 \times 365) + (0.5 \times 500,000 \text{ x } 4) = 31,838,000$ kg = 31,838 tons

The causes of increase are urbanisation, population growth and the changing of the consumer's attitude.

Please note that these numbers differ from the estimation given earlier. This is due to the fact that each prediction of future waste production will vary depending on the number of people and tourists assumed as well as their change in waste production habit. There is no such thing as the right prediction unless we know the actual value, which we cannot as it lies in the future.

Development of substrates

According to the report of the Public Project Management Board and Department of Natural Resources And Environment of Phu Quoc district, the amount of waste which can be collected in recent years is increased. The collected waste comes mainly from residential areas such as two towns Duong Dong, An Thoi and Ham Ninh commune.

A higher collection rate is estimated for 2005 - 90% and considered to increase in the following years up to 95%.

According to the assessment of the Department of Natural Resources and Environment - Construction and Transport of Phu Quoc district, in coming period, the residential waste in Phu Quoc will be increased as follows:

Table 4-20: Anticipated residential waste for renewable energy on Phu Quoc in the period 2005-2010[50]

Year	Total estimated waste amount (tons)	Share of collection (%)	Annual collected waste amount (tons)
2005	16 445	90	14 800
2010	31 838	95	30 246

As a matter of fact, estimations are changing in a certain range depending on sources (e.g. authorities) and comparisons with similar regions (national authorities, World Bank). Therefore, the amount of substrates used as basic load in this feasibility study, was chosen to be 15,500 tons. According to the estimations made above, the annual waste amount for 2010 will be approx. 30,000 tons rising up to 60,000 tons until 2025.

Energy Content of Substrate

The delivered waste with a lower heat value of about 8000 MJ/Mg is not appropriate to burn it in a stable process producing electricity effectively.

In order to ensure a stable combustion process, it is necessary to

- shredding the input; this maximizes the surface of the fuel particles and thus supports the combustion process
- sort out inert material like minerals, glass, metal to increase the heat value as well
- dry the input to increase the heat value

The physical characteristics of the input in the conditioning process are displayed in the following table:

[49] *Public Project Management Board, Phu Quoc*

[50] *Department of Natural Resources and Environment-Construction and Transport, and Study Team of IE*

In step 1 inert material is sorted out by hand. It is estimated, that 50% of the inert material can be separated out of the process. In practice, the share, which can be sorted out, depends mainly on the amount of the sorting staff.

The separated inert material consists of

- Metal
- Minerals from anorganic origin
- Minerals from organic origin

Metal is even as won in the described way a valuable material and can be sold.

Minerals from organic origin are suitable to seal ways to the landfill and in the landfilling area.

Minerals from organic origin should for hygienic reasons be landfilled directly.

Table 4-21: Characteristics of the input in the conditioning process

Characteristics	Unit	Input	after Sorting	After drying
Mass	Mg	15500	14725	9387
Volume	m^3	28182	26773	17068
Percentage dry mass	%	51	51	80
Mass dry substance	Mg	7905	7510	7510
Lower heat value	MJ/Mg	8310	8750	13500

The sorting process decreases the input mass at about 5%. The increase of the lower heat value is also about 5%. The sorting process does not improve the combustion characteristics significantly, but is nevertheless recommended due to its easy instalment and the valuable separated materials.

With the solar drying, the quality of the waste can be treated in a way, that the output is usable as a fuel. The water content can economically be decreased from about 50 % in the input to about 20 % after drying. The lower heat value increases from about 9000 MJ/Mg to 13500 MJ/Mg.

Even better drying rates might be reached in practice. So far, there are only few experiences with solar drying under comparable conditions like on Phu Quoc.

4.3.1.1.3 Process Dimensioning

The annual waste amount to treat is determined with 15500 Mg/year. This corresponds to 50 Mg/working day. Considering seasonal influences, the maximum daily amount is estimated with 70 Mg/working day.

For the following dimensioning calculation, a storage capacity of one week, 70 Mg/working day x 6 days = 420 Mg is assumed.

System

Conditioning

At a given density of 500 kg/m³ and a maximum storage height of 3m, the needed storage space in the delivery area is 280 m². Considering an additional area to handle/shunt the waste, the delivery area should have 500 m².

The needed area for sorting is estimated with 150 m². If the separation of further fractions apart from metal, glass and minerals from the waste stream is foreseen, additional space is needed.

The crushing area is dimensioned with 150 m²

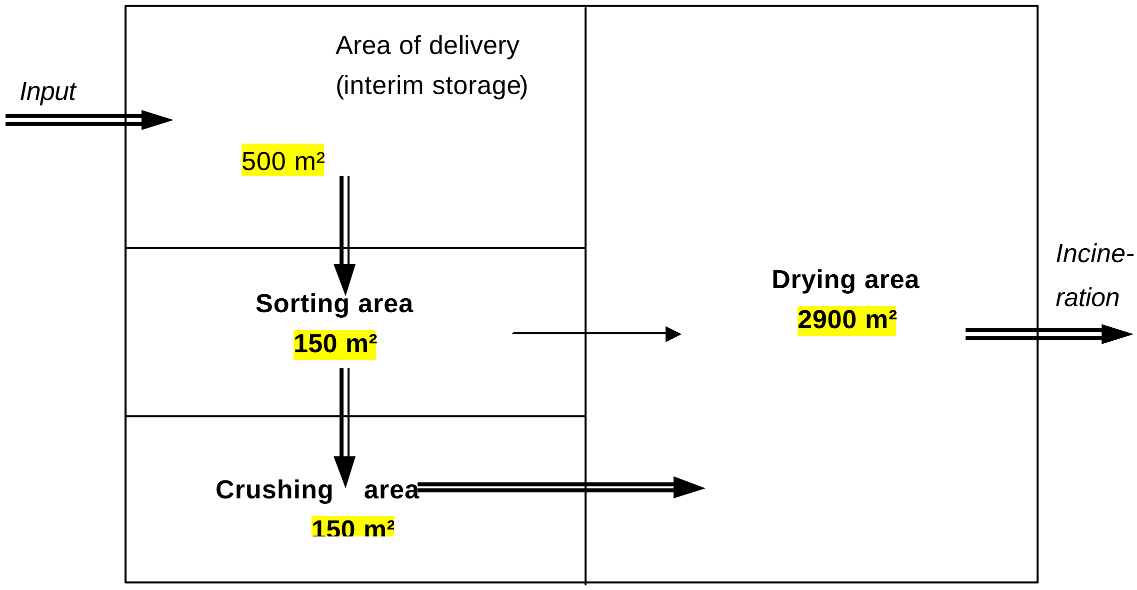


Figure 4-26: Space requirements in the conditioning area

The specific evaporation rate of comparable drying plants in Europe for the drying of sewage sludge is around 1000 kg H_2O/m^2 drying area. On Phu Quoc, the evaporation rate is calculated with about 2200 kg H_2O/m^2 drying area without major variations between the seasons. This is especially due to the climatic conditions, but also to the more complex structure of the waste compared to sewage sludge. Considering a further storage and additional area to shunt the waste (30 %), the drying area is 2900 m²

Incineration/power generation

The spatial needs of the incineration/power generation unit (excluding storage) are 1500 m².

Considering all other necessary space for the plant with 50 %, an overall area of 7800 m² for the whole plant is needed.

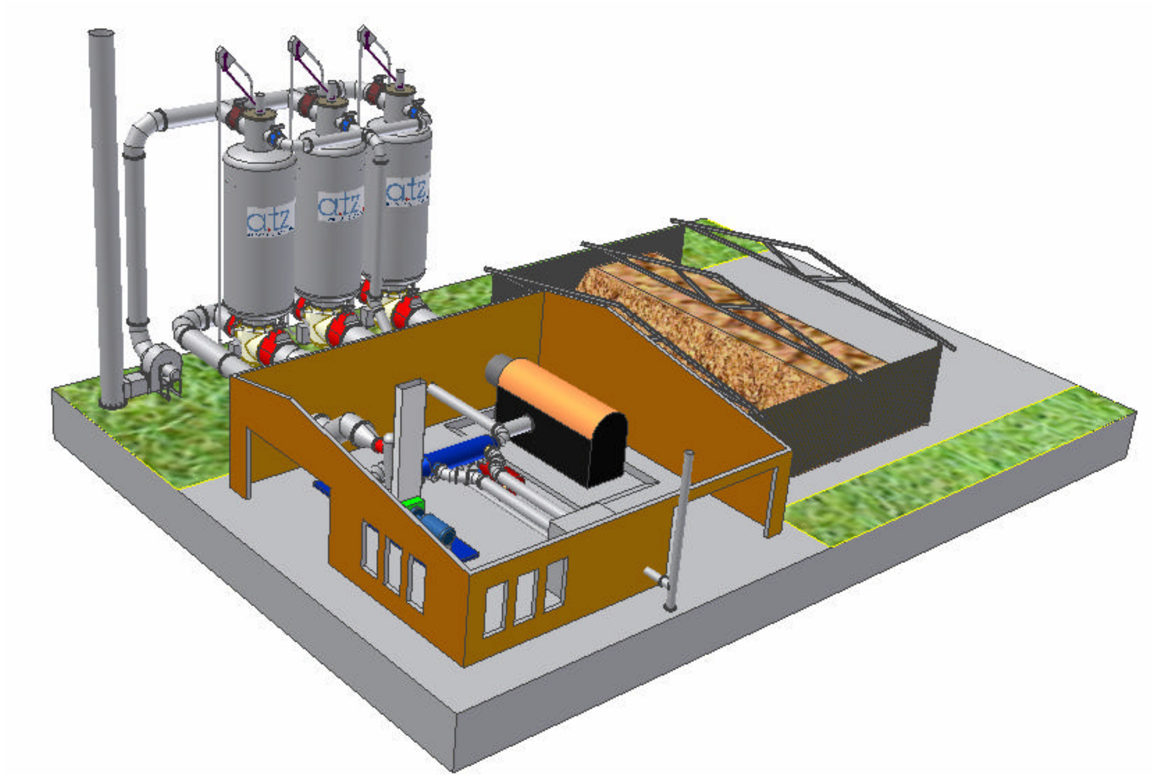


Figure 4-27: Scheme of combustion plant [Source: ATZ]

Availability

Waste is continuously produced and delivered to the plant. Its amount and quality varies not significantly between the seasons: Only 12% of the annual waste amount is produced by seasonal activities, tourism and fishery.

To prevent extensive interim storage of waste with all unwanted accompanying phenomena like smell and risk of fire, the plant concept implies a mostly continuous operation of the plant components.

Conditioning

The delivery area is planned as a first interim storage with a capacity of one week as a minimum. A longer interim storage of the waste should be prevented to avoid anaerobic processes and self-ignition in the material.

The risk of a break down of the sorting belt is relatively low. Repairing is as a rule uncomplicated. In case of a breakdown, the sorting may be done in the delivery area alternatively. The sorted materials will be brought to the crushing area directly by wheel loader.

Although, many improvements were made in the last few years, crushing of waste is still a process with a high risk to get a breakdown in the machinery. The plant concept foresees three alternatives to minimize the effects of a breakdown: Firstly, the interim storage has a capacity of at least one week. Thus, a probable repairing/planned maintenance may take one week as well. Secondly, with a crushing capacity of about 75 m³/hour, the maximum delivery of 70 Mg/day may be crushed in two hours only. This ensures a quick reworking of waste after a breakdown.

As a third alternative, bulky material is sorted out manually before crushing. In this case, the sorted waste is brought directly into the drying area. Bulky waste is stored and crushed later.

With a proposed running time of 1600 h/year, only 25% of the possible capacity of the crushing aggregate is reached with the given waste amount.

The drying process is planned to operate continuously. The retention time of the waste in the drying area is 2-3 weeks to minimize the water content to less than 20%. When an interim storage of the fuel is necessary, the heaps of the waste may be raised up to 200% and thus double the storage capacity. The disadvantage of this procedure is a less effective drying process, which may cause problems in the incineration process due to a different lower heat value.

Incineration/power generation

The incineration/power generation is planned to operate continuously 7000 hours per year. Two annual regular shutdowns are foreseen for repair and maintenance. Due to described storage facilities, the favourable maintenance rate is one week, but it should not exceed 2 weeks.

Capacity

The whole plant including conditioning and incineration/power generation, is designed to treat 15,500 Mg waste per year. Minor seasonal variations of the input are considered, but a major increase of the capacities is only possible with an expansion of the plant components.

The only component, which is not limited so far is the crushing aggregate. It is designed to run 1,600 hours/year with a throughput of 75 m^3/hour. With the foreseen plant specifications, the crushing aggregate runs with less than 25% of its capacity.

4.3.1.1.4 Energy Generation and Distribution

With a lower heat value of 13,500 MJ/Mg and an annual mass of 9,400 Mg, the theoretically producible energy of the conditioned fuel is 5,050 kW.

With the foreseen plant design an electrical efficiency of 24.6% is calculated. It corresponds to an electrical power of 1240 kW, including the need of electricity of the incineration module. The use of additional and more efficient equipment like the installation of a third pebble heater can raise the electrical efficiency theoretically up to 35%. Due to reasons of dependability and economy, a less efficient solution is favoured.

Relevant electricity needs in the plant are

- support of the air transport through the drying area
- transport of the waste by belts
- lighting/others

The specific energy need of the drying process is about 20 kWh/Mg H_2O. For an exfiltration of 9700 Mg water per year, 194,000 kWh are needed. This corresponds to an electrical power of 28 kW or 2.5% of the produced power.

The need of all other facilities is estimated with 450,000 kWh, corresponding to a rate of 5.2% of the produced power.

The energy potential for sale is 8.0 MWh per year.

4.3.1.1.5 Land Requirement

The needed land is calculated with 7800 m². 67% (5200 m²) of it are built up and roofed for conditioning/incineration purposes. The remaining 33% (2600 m²) of the area are foreseen as traffic/parking space and for other purposes. This area is sealed with gravel in order to ensure its practicability with trucks and front loaders, even in the rainy season.

Table 4-22: Overview on land requirement of a combustion plant

Component	Area [m²]
Delivery/storage	500
Sorting area	150
Crushing area	150
Drying area	2900
Incineration/ power generation	1500
Additional area	50% = 2600
Sum	**7800**

4.3.1.1.6 Process Parameters and Maintenance

Drying process

The drying process bases on a water transfer from the waste into the air. Waste and air are heated by solar radiation, convection and biodegradation processes in the waste from ambient temperature (about 27°C with low seasonal variation) to e.g. 60°C. Higher temperatures might be possible in months with a high daily sunshine duration (Max: February with 7.5 h). The output temperature of the air between night and day varies not significantly.

<u>Input waste:</u>

Amount: 14725 Mg/a

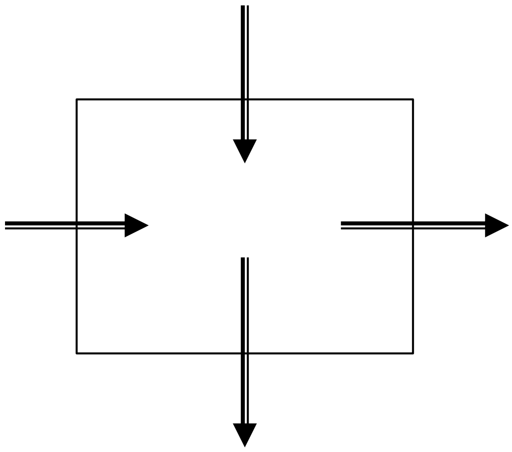
Moisture: 49 %
Lower heat value: 8750 MJ/Mg

<u>Input air (climate data):</u>

Temperature:
25.6-28°C

Moisture
70-80 %
16.1 –28.8 g H_2O/m^3

5.500 Nm^3/h



<u>Output air :</u>

Temperature:
average 60°C

Moisture
95 %
123 g/m^3

<u>Output fuel:</u>

Amount: 9,387 Mg/a

Moisture: 20 %
Lower heat value:
13,500 MJ/Mg

Figure 4-28: Scheme of drying process

To transport the water outside the drying hall, an average air stream of e.g. 5,500 Nm^3/h is necessary.

No major maintenance, which would provide an interruption of the drying process, is necessary.

Incineration/power generation – general process parameters

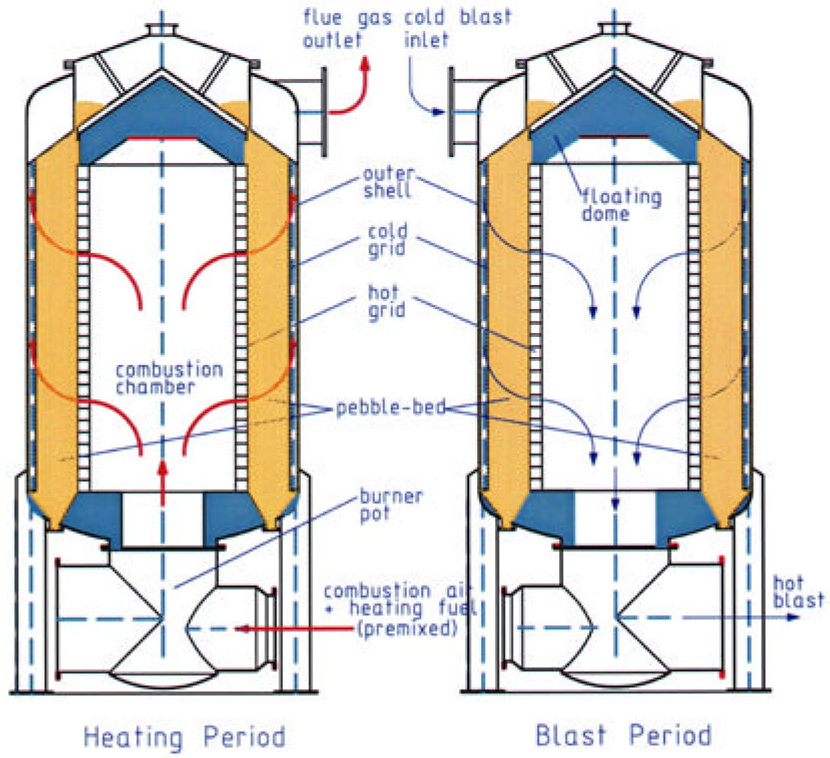


Figure 4-29: PEBBLE-Heater with radial fluid flow [Source: ATZ]

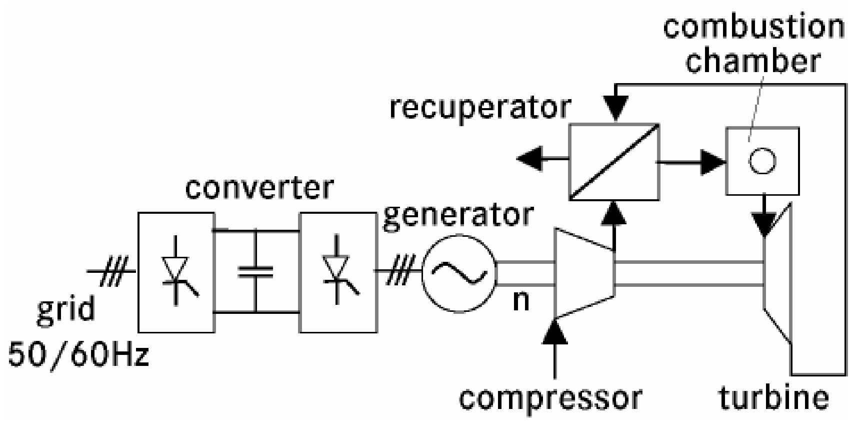


Figure 4-30: Schematic diagram of the microturbine [Source: ATZ]

The ambient air (15°C) is first compressed to 4.50 bar in a compressor driven by a gas turbine. Due to compression its temperature rises to 205°C. In an after-cooler it is cooled down to 90°C in a recuperative heat exchanger. The available heat may be used for a heat consumer, e.g. as hot water or low temperature steam. Decreasing temperature before entering the first Pebble-Heater (PH1) is important for lowering the stack losses. Lower input temperature at PH1 enables lower outlet temperature at PH2.

After the cooler, the compressed air enters the first Pebble-Heater, where it is heated to 830°C. With that temperature the hot air enters the gas turbine, where it is expanded to almost ambient pressure (1.03 bar) and to a temperature of 542°C. The released expansion work is used for compressor and generator drive.

The most part of the expanded air is used as preheated combustion air for the biomass combustor. The rest may be used for another heat consumer, at a higher temperature level. As it is pure air, it may very well be used for drying processes, even in the food industry. Of course it may be used for drying the input biomass fuel, thus increasing the efficiency of the power production.

Biomass is fueled into the combustion chamber and burnt with preheated (542°C) combustion air. Due to a high air factor, combustion gases have a relatively low temperature of 870°C. That prevents the sintering of flying ash. Depending on the kind of biomass and on its ash characteristics, that temperature may be further decreased (or increased as well). Depending on the ash content, it may be necessary to include a hot gas cleaning system (e.g. a hot gas cyclone or a filter bed) before entering the Pebble-Heater from the hot side (the so-called hot grid), where there is a homogeneous temperature field (870°C). If there are still some tar particles in the gas stream, they will at least be extracted there and certainly burnt. The combustion gases are cooled down to 97°C and exhausted through the stack. This temperature may be controlled (e.g. by the cooled compressed air temperature at PH1 inlet) and adjusted to the type of biomass used, i.e. to the actual sulfur and moisture content, in order to avoid cold-end corrosion.

The cycle with such parameters will result in an electric efficiency of 32.3%. In case the heat from the air after-cooler and from the hot air at the turbine outlet may be used, the total efficiency of the CHP plant will be about 71%. Those results are obtained with the following parameters:

- isentropic efficiency of compressor $\eta_{ic} = 80\%$
- isentropic efficiency of gas turbine $\eta_{iT} = 83.7\%$
- product of mechanical and electrical efficiency at generator $\eta_{mech} \cdot \eta_{el} = 93.5\ \%$
- thermal efficiency of biomass combustor $\eta_{comb.} = 95\%$.

Figure 4-31: Process description of the combustion process by PEBBLE HEATER

Two annual regular shutdowns are foreseen for repair and maintenance. Due to the necessary continuous delivery of the waste and the limited storage facilities, the favourable maintenance rate is one week, but should not exceed 2 weeks.

4.3.1.1.7 Interfaces with Existing Systems

Input

The potential input into the plant is waste with an amount of 15,500 Mg/a from the whole island.

Though the currently eligible locations for the plant are not easy to be delivered from all waste sources, a decentralised pre-conditioning of waste or a waste transfer station seem not to be economically reasonable.

The potential use of further input material, e.g. wood, is with 7% of the overall input potential not significant enough to be considered due to the relatively small amounts.

Output

The relevant output streams are

- Electricity - 8 MWh/a
- Heated air – 44,000 Kg/h with 140°C
- Ash – 1510 Mg/a
- Sorted materials 775 Mg/a

The electricity should be fed into the public electricity net, replacing electricity produced with diesel engines. The conditions of the necessary wiring system are not part of the feasibility study. It should be regarded detailed in the planning stage.

An external consumer of the heated air is not available at the moment. Possible types of use are internally the support of the waste drying process or externally the drying of products from forestry or the food industry.

A further use of the ash is not recommended. Among others because of the annual ash amounts, a favourable plant location is near the landfill.

The materials, which were sorted out manually, consist of various fractions and may be recycled/ landfilled further depending on their characteristics.

4.3.1.1.8 Comparison to other Existing Plants and References

The incineration of waste in developed countries is due to its high amounts of potentially hazardous substances a complex and expensive process. An economical operation size of such plants is as a rule above 100,000 Mg per year. The population density and the high waste amount per capita guarantee short transport ways from the source to the incineration. Differing from the proposed plant, the minimisation and stabilisation of waste is the main target; the production of electricity plays not an important role in countries, where it is relatively cheep and easily available. The conditioning is as a rule limited to the crushing of bulky waste.

The described plant design bases on the concept, that the waste derived fuel is extensively conditioned. As a result, it has a high calorific value and is largely free from hazardous substances after pre-sorting. The technology ensures a widely complete removal of the remaining solid particles out of the flue gas. A relatively high mass-specific amount of electricity is produced, an expensive treatment of the flue gas and the resulting ash are not necessary as necessary.

The plant design is very innovative, but so far unique.

The solar drying on a comparable scale is in use under much more difficult climatic conditions in Germany drying sewage sludge. More than 20 plants are working there with this or a similar principle.

The pebble heating technology is in use on pilot scale for some years, which allows a relatively precise planning on a larger scale already.

4.3.1.2 Utilisation/Disposal of Residues

4.3.1.2.1 Quantity of Residues

The amount of ash to be landfilled is calculated with 1510 Mg/a.

Further solid residues are sorted materials, which are not recyclable, especially inert materials. Its amount is estimated with 600 Mg/a.

4.3.1.2.2 Utilisation/Disposal

There are two basic questions to be answered in order to decide about the further utilisation of single fractions :

1. Which fractions should be sorted out to ensure an optimal incineration?
2. Which fractions are marketable?
3. Is the separation of valuable fractions with high calorific value desirable?

In this study, the separation of fractions, which disturb or inhibit the incineration process was set as the main target. Only the following fractions have been chosen to be separated.

- Metal
- Glass
- Minerals

In this case, the mineral fraction may be used further to build/maintain ways on the landfill. Depending on the quality and the market, the metal may be recycled. The glass fraction should be landfilled directly.

4.3.1.3 Infrastructure

4.3.1.3.1 Storage of Substrate

The storage capacities of the plant consist of the delivery area and the drying area. Further roofed storage capacities are not planned. Unroofed storage is especially unfavourable in the raining season due to the increasing water content.

The delivery area is planned as a first interim storage with a capacity of 350 Mg. This corresponds to one week as a minimum. A longer interim storage of the waste should be prevented to avoid anaerobic processes and self-ignition in the material.

The drying process is planned to operate continuously. The retention time of the waste in the drying area is 2-3 weeks to minimize the water content to less than 20%. When an interim storage of the fuel is necessary, the heaps of the waste may be raised up to 200% and thus double the storage capacity. The disadvantage of this procedure is a less effective drying process, which may cause problems in the incineration process due to a different lower heat value. A further possible disadvantage is the accruement of anaerobic zones.

4.3.1.3.2 Transport Infrastructure

Two major material streams are to be considered in planning, the delivery of waste and the transport from the ash to the landfill.

To ensure a continuous transport independent from the season to and from the plant, a sealed way passable by trucks is necessary.

4.3.1.4 Summary of the Technical Assessment

A combination of a solar drying process and a combustion plant with energy recovery by the innovative Pebble-Heater technology seems to be a suitable solution to

- to minimize the amounts of waste and its hazardousness
- to produce energy out of the waste

The solar drying raises the heat value of the input without the use of further external resources and stabilizes it biologically. A pre-sorting process stage improves working conditions and efficiency of the scavengers significantly and excludes unwanted material from the further process.

The Pebble-Heater functions as a filter and reduces the emissions of dust, aerosols and tar by 50% compared to other technologies.

The electrical efficiency of the Pebble-Heater technology is with up to 30% much higher than for all other technologies set into practice. The Electricity output is estimated with about 8 MWh for an overall input of 16,000 Mg waste per year.

4.3.2 Economic Assessment

4.3.2.1 Costs

4.3.2.1.1 Excluded Costs

The amount of some types of costs may not be specified without identifying the site of the plant. These costs are not regarded in this feasibility study, even though they play a significant role.

Excluded costs are especially **infrastructural costs**:

- Plant area
- Sealing of the plant area
- Connection to the transporting system (sealed way)
- Connection to the public wiring system
- Water supply
- Others

If actually excluded infrastructural costs are considered, the investment costs might be one or two times higher than calculated here.

4.3.2.1.2 Investment Costs

The investment costs include the production of the equipment only. Planning and transport costs of the machinery are excluded.

The building and equipment costs of the incineration/power generation unit are calculated with 4.8 million Euro[51]. The main investment costs of the conditioning area are the costs for the erection of the building with 703,000 €. The costs of the technical equipment are with 200,000 € less relevant. Other costs are planned for common rooms and security/hygienic installations for the staff and workshop equipment.

Table 4-23: Investment costs and amortisation time for several components of the combustion plant

	Investment costs [€]	**Amortisation time [a]**
Incineration/power generation unit	4 800 000	15
Building conditioning area	703 000	20
Wheel loader	50 000	15
Sorting equipment	20 000	15
Crushing machine	110 000	5
Drying equipment	20 000	15
Other	50 000	15
Sum	**5 753 000**	

The overall investment costs amount to 5.7 million Euro.

4.3.2.1.3 Operating and Maintenance Costs

Costs for operation and maintenance contain all costs, which occur during one year. This are in detail:

- Capital costs (amortisation)
- Repairing and maintenance
- Operating costs including fuel, lubricants (electrical power supply is provided internally)
- Tax, insurance

Personal costs are expelled separately.

Table 4-24: Operating and maintenance costs

	Annual costs [€/a]
Equipment	
Incineration/power generation Unit	960 000
Building conditioning area	117167
Sorting equipment	4 000
Wheel loader	13 000
Crushing machine	67 000
Drying equipment	4 000
Other	10 000
Staff	
10 Persons	20 000
Sum	**1 195 167**

The annual costs of the incineration plant are calculated with 1.2 million Euro.

With an annual electricity output of 8000 MWh, the specific costs amount to 0.15 €/kWh.

4.3.3 Environmental Assessment

The exact assessment of the anticipated environmental impacts is beyond the possibilities of a feasibility study. For the accurate determination of impacts more data are needed.

Responsible planning needs to consider all limiting and contributing factors, leading to collection evaluation and interpretation of the data in an explicit Environmental Impact Assessment (EIA) according to acknowledged standards. For the EIA on-site inspections, measuring and monitoring are highly important.

[51] ATZ

During evaluation and visits no clear decision concerning the final site has been made. Even on repeated request in December 2005 the planning committee did not bring out a final decision. The following data and conclusions are based on the data available from the visit in December 2005 and the additional material provided.

4.3.3.1 Local Impact

The plans go towards locating the plants as far as 3km away from settlements to avoid disturbances. Considering the need of poor people such as so called “waste pickers” to use recyclable wastes for survival and their willingness to live close to these facilities in informal settlements, measures such as fencing have to be taken. However, distances of 300 m are more realistic which by the way correspond with European standards. Thus, disturbances of formal settlements can be screened out. Informal settlements are hard to predict and should therefore not determine in initial planning but measures such as the mentioned fencing need to be considered.

The following sub-chapters briefly evaluate the impacts of solid-state fermentation in consideration of the given environmental factors such as climate, social and cultural habits, waste generation and composition on a local scale.

4.3.3.1.1 Air – no significant impact

Potential positive impacts caused by the project implementation are based on the replacement of fossil fuel, leading to a reduction of local air pollution. On the other hand, the combustion plant and maintenance might also contribute to the increase of local traffic (transport to/from the plant). Important in this context is the contribution towards the use of renewable energies and the local contribution in CO_2 minimization in electricity generation on a local scale.

4.3.3.1.2 Waste – considerable positive impact

One important benefit of the combustion plant is the significant improvement of local environmental conditions by pre-treatment and reducing the amount and hazardousness of the waste. The reduction of unmanaged and informal dumping areas will increase the number of recreational areas and subsequently help promoting the development of the desired eco-tourism on the island by minimizing the impact of waste generation on the island and preserving the natural environment.

4.3.3.1.3 Soil – considerable positive impact

The pre-treatment of household waste can minimize the amount and hazardousness of landfilled waste to the environment: Less landfill capacities are necessary and furthermore, emissions of methane containing gases, odours and leachate water are minimized.

4.3.3.1.4 Water – positive impact

The leachate generation from informal and badly designed, managed and maintained waste dumping grounds will decrease significantly with the installation of a treatment plant.

4.3.3.1.5 Noise – no significant impact

The local use operation of a combustion plant instead of diesel engines will not change the impact of noise by power generation significantly, a small noise reduction is expected. Nevertheless, the noise caused by transportation and collection of substrates needs to be monitored.

The overall noise exposure for the neighbours can be neglected because of the planned distances of 500-3000m to the closest formal settlements. However, factors such as noise-carrying winds have to be taken into consideration. For exact assessment long term noise monitoring or extensive noise prediction are needed.

4.3.3.1.6 Odour – positive impact

Currently the unmanaged informal landfills and disposal sites cause frequent odorous impact throughout the region.

The combustion process does not emit significant odour impacts. The main odourous impacts of the plant are caused by the conditioning; especially the drying process. In opposite to the uncontrolled anaerob and aerob biodegradation processes on dumping grounds, a controlled aerob composting/drying emits less smells.

An impact for neighbouring communities is not likely to be expected because of the planned distances.

4.3.3.2 Global Impact

By using renewable instead of finite resources to produce energy promote the aim of the Kyoto protocol. Unused energy resources get used and the released carbon stays in a steady cycle or gets bound.

4.3.3.2.1 CO_2-Saving Potential

Reduction of greenhouse emissions by methane capture and use

Greenhouse effect is caused by gas emissions to the atmosphere which allow the sun's short wave radiation to reach the earth surface while adsorbing, to a large degree, the long wave heat radiation from earth's surface and atmosphere. The "greenhouse gases" (gases influencing the greenhouse effect) are: water vapours (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). The increase of the greenhouse gases leads to rising temperatures. An instrument for lowering the greenhouse effect is the reduction of CO_2-emissions. Besides CO_2 the presence of other greenhouse-gases (e.g. CH_4) also contributes to global warming. Theses gases generally exist in significantly smaller quantities, but hold an outranking global warming potential. Methane, which is produced in anaerobic processes, contributes with 20% to the greenhouse effect (while CO_2 = 62%) but it has a 25 times higher global warming potential compared with CO_2 [GTZ Biogas Digest].

Each ton of methane that is beneficially used is equivalent to 25 Mg of carbon dioxide as contribution to the greenhouse effect. That shows the urgent need and the high benefits for sustainability of controlled biogas generation and collection generated from household wastes.

Table 4-25: Relative climatic change potential caused through different greenhouse gases within a period of 100 years after the emission, data mass equivalent of CO_2

Gas	**Relative global warming potential 20 years after emission**	**Relative global warming potential 100 years after emission**
CH_4	63	24.5
N_2O	270	320
$FCKW_{12}$	n.	8500
CF_3Br (Halon 1301)		5600
C_2F_6 (Perflourethan)		12500

[Source: ENQUETE-COMISSION (1992)]

On the worldwide scale, from the 30 million tons of methane emissions per year produced by solid waste storage, anaerobic lagoons, liquid/slurry storage, pasture etc. (animal waste management), a significant amount can be reduced by a suitable pre-treatment of waste.

Reduction of nitrous oxide emissions

Compared with CO_2 the relative per kg climate change potential of Nitrous oxide (N_2O) is 320 times higher [GTZ Biogas Digest]. Therefore, nitrous oxide is subject in regulations focusing on reduction of greenhouse gases such as the Kyoto Protocol. Besides carbon dioxide and methane, nitrous oxide is the third most important gas that contributes to global warming.

In a combustion process, the accruement of nitrous oxides is minimized by several measures: Firstly, a high excess air rate ensures a complete oxidation. The calculations were done for an excess air rate of 7.42. Secondly, the combustion temperature influences the amount of NO_2. Thirdly, there are further chemical measures to minimize nitrous oxides.

4.3.3.2.2 Potential Applicability as CDM Project

In future it may be possible to generate additional income with RE by Clean Development Mechanism. Some estimations expect prices of 3-6 \$/tCO_2equivalent (*CD4CDM*)[52]. Energy production from biomass or biogas has rather low costs for CO_2 reduction and therefore it may be a competitive solution for CDM.[53] But because of the expected rather low price, unclear framework conditions, the need for control and certain transaction costs it seems currently CDM will be an option only for big projects. Conditions for CDM may change quickly; it is worth observing the actual situation.

[52] Emission trading takes also place at the European Energy Exchange see: http://www.eex.de/index_e.asp (current price 8.72 €)

[53] Tuan and Nguyen 2002, in BiWaRE

4.3.3.3 Summary of the Ecological Assessment

The ecological and environmental contribution of implementing combustion of waste combined power generation is very beneficial for Phu Quoc Island. The positive local impacts overbalance the negative by far.

4.3.4 Regulatory and Permitting Requirements

Different legal requirements have to be met according to national standards and actual law. The following chapters give information about the legislation and decrees specifically for the installation of a waste combustion plant with power generation.

4.3.4.1 Compliance with the Regulations

For clear separation of responsibilities and overview reasons this chapter is divided into "Building Regulations", "Environmental Regulations" and "Operational Safety Regulations"

4.3.4.1.1 Building Regulations

In Vietnam, the law in construction is a collection of documents that is promulgated by the government to adjust the issues in economy, social sector, technology and art that arise from and during a construction process (included new buildings, reconstructions, repairs), as well as basic construction fields (industry, infrastructure) and civil constructions (the house).

This law shall apply to domestic organizations and individuals as well as foreign organizations and individuals investing into constructions and engaging in construction activities within the territory of the Socialist Republic of Vietnam. Is an international treaty signed or acceded by the Socialist Republic of Vietnam to contain provisions which are different from those in this law, the provisions of such international treaty shall apply.

In addition, during the investment and construction process the investor, tender and constructor has to follow the obligations issued in these regulations:

The main regulations on investment and construction of a project are mentioned in the following documents.

Table 4-26: Building and Construction Regulations for combustion facilities in Vietnam

No.	Name of document - date of issuance - issuing authority	Contents
1	Decree No. 52/1999/ND-CP, dated 8-7-1999; Decree No. 12/2000/ND- CP, dated 05-5-2000 and Decree No. 07/2003/ND-CP, dated 30-1-2003 - by the Government	Regulations on investment and construction management for project on Vietnam territories, include: – Conditions for starting construction of a project; – Types of projects which need to get construction license; – Competent authorities to issue construction license; – Time for issuing construction license; – Conditions and capabilities of contractors; – Written approval of bidding results and contents of contracts in necessary cases; – Procedures need to be performed after completion of the project.
2	Interministerial Circular No. 09/1999TTLT-BXD-TCDC by Ministry of Construction and Geological General Department	Concrete regulations on issuing construction license: – Who need construction license; – Construction management of the project with construction license exemption; – Background for issuing construction license; – Documents necessary for issuing construction license; – Competency for issuing construction license; – Procedures for issuing construction license and inspection of implementation; – Responsibilities of project owner on implementation progress, quality and safety of the construction project;
3	Circular No. 08/2003/TT, dated 9-7-2003 - by Ministry of Construction	Guidelines on contents and management of EPC contracts: – Requirements on preparation of Documents on requirements of the project owner; – Regulation on preparation of bidding documents; – Conditions and capability of EPC contractor; – Contract documents, contract price, payment in advance and liquidation; – Responsibilities and rights of project owner and EPC contractor in management and implementation of the contract.

No.	Name of document - date of issuance - issuing authority	Contents
4	Decision No.19/2003/QD-BXD, dated 13-7-2003 by Ministry of Construction	Concrete regulations on conditions and capability on construction activities (construction investment consultancy, installation and construction of project types): – Organization for establishment of investment-construction project: Requirement on recruitment or contract on labour, skills, degree of required positions such as project manager, leader of professional part of the project. – Project management unit: requirements on qualification, degree, experience in management for main positions (leader, deputy leader, technical head, economic head etc.). – Construction investigation contractor: requirement on number of qualified staff in terms of skills, experience for main positions such as in charge of investigation or professional areas. – Project design contractor: requirement on number of contracted labours who meet conditions on ability, professional license for project designing like this project for taking positions of project design manager and other managers as required. – Construction supervision contractor: With enough contracted labours meeting conditions on ability, degree, qualifications, experience for positions of chief supervisor and professional supervisors. – Contractor for reviewing quality of the project: Has enough experts for carrying out checking, reviewing quality, has standard laboratory as specified in regulation. The person in charge must have labour contract with the contractor according to requirement of laws. – Project construction and installation contractor: Has legal status, enough labours meeting requirement of project construction and installation works; has machines, equipment for construction ensuring technical, quality and safety requirements suitable to the project; has suitable quality management system, ensuring insurance related to works; has enough labours in terms of skills and qualifications for main positions such as Chief of construction and in charge of construction technique. – Main contractor: Has sufficient qualifications and experience as required; directly carrying out the main works and at least carrying out 70% works for design contractor and over 50% for construction and installation contractors. – Capabilities required for EPC contractor: Has capabilities as required for all the above mentioned contractors and has enough experience as EPC contract implementation.

No.	Name of document - date of issuance - issuing authority	Contents
5	Decision No.1242/1998 QD-BXD, dated 25-11-1998	Issuing "unit costs for basic construction works"
6	Circular No. 109/2000/TT-BTC, dated 13 -11-2000 by Ministry of Finance	Fees for investment appraisal works
7	Degree No 709/QD-NLDK, dated 3/4/2004 by MOI	Guideline Draft for Economic - Financial analysis and ceiling electricity purchasing and selling price for investment project of power sources.

4.3.4.1.2 Environmental Regulations

Similar to the Construction Law, all projects in Vietnam have to follow all articles mentioned in the Environmental Protection Law. The regulations stated below should be referred to during preparation and implementation of the project.

Table 4-27: Environmental Regulations for combustion facilities in Vietnam

No.	Name of document - date of issuance - issuing authority	Contents
1	Circular No. 55/2002/TT-BKHCNMT, dated 23-7-2002 by MOSTE	– Guidelines on reviewing technologies and environmental issues of investment projects. – Regulation on the projects which have to be reviewed. – Contents to be reviewed in terms of environmental aspects: environmental polluting resources, solid, liquid, gas pollutants produced during production process etc., environmental accident risks and mitigation measures.
2	Circular No. 490/TT-BKHCNMT, dated 29-4-1998 by MOSTE	Guidelines on preparation of and reviewing environmental impact assessment report for the investment projects.
3	TCVN 5949 : 1998	Regulation on maximal permissive noise level by time in day in the public and residential areas

No.	Name of document - date of issuance - issuing authority	Contents
4	TCVN 5939 : 1995	Regulation on air quality - Standards on industrial flue gas (dust and inorganic substance concentration in industrial emission discharged in industrial zones).
5	TCVN 5940 : 1995	Regulation on air quality - Standards on industrial flue gas (Organic substances in industrial emission discharged in industrial zones).
6	TCVN 6991 : 2001	Regulation on air quality - Standards on industrial flue gas - (Standards on inorganic substances in industrial emission discharged in industrial zones).
7	TCVN 6994 : 2001	Regulation on air quality - Standards on industrial flue gas - Standards on organic substances in industrial emission discharged in industrial zones.
8	TCVN 6992 : 2001	Regulation on air quality - Standards on industrial flue gas - Standards on inorganic substances in industrial emission discharged in urban zones.
9	TCVN 6993 : 2001	Regulation on air quality - Standards on industrial flue gas - Standards on inorganic substances in industrial emission discharged in rural and mountainous zones.
10	TCVN 6995 : 2001	Regulation on air quality - Standards on industrial flue gas - Standards on organic substances in industrial emission discharged in urban zones
11	TCVN 6996 : 2001	Regulation on air quality - Standards on industrial flue gas - Standards on organic substances in industrial emission discharged in rural and mountainous zones.
12	TCVN 5945 : 1995	Regulation on industrial effluents discharge - Standards
13	TCVN 6980 : 2001	Water quality - Standards for industrial effluents discharged into river used for domestic water supply.
14	TCVN 6982 : 2001	Water quality - Standards for industrial effluents discharged into river used for water sports and recreation.
15	TCVN 6983 : 2001	Water quality - Standards for industrial effluents discharged into lakes used for water sports and recreation.
16	TCVN 6984 : 2001	Water quality - Standards for industrial effluents discharged into river used for protection of aquatic life.
17	TCVN 6985 : 2001	Water quality - Standards for industrial effluents discharged into lakes used for protection of aquatic life.
18	TCVN 6986 : 2001	Water quality - Standards for industrial effluents discharged into coastal waters used for protection of aquatic life.

No.	Name of document - date of issuance - issuing authority	Contents
19	TCVN 7440 : 2005	Standards on emissions in electric power industry
20	Decision No.07/2005/QD-BTNMT dated 20-9-2005	Decision an application of Vietnam standard TCVN 7440 : 2005 – Standards on emission in thermal power industry

Note: TCVN: Vietnamese standard

4.3.4.1.3 Operational Safety Regulations

The responsibility for production, distribution, and sale of electricity on Phu Quoc lies with the Electric Power Company 2 in Kien Giang province, regional subsidiary of the national state-owned utility Electricity of Vietnam (EVN). The initiative to complement the island's electricity system with renewable energy technologies was received well by the Electric Power Company 2.

In general, the operational safety regulations for power generation are mentioned in the following documents.

Table 4-28: Operational Safety Regulations for biogas facilities in Vietnam

No.	Name of document - date of issuance - issuing authority	Contents
1	Regulations on safety for electrical equipment of power plants and power network- ministry of Electricity - 1984. (Volume I: equipment of power plants and substations) - issued together with Decision No.25DL/KT, dated 22-01-1985 by Ministry of Electricity.	– General requirements for persons who directly work on management, operation of electric equipment in power plants and substations with voltage up to 1000 V and above 1000 V (heath, qualifications, trained, periodical check and ranked on technical degrees on technical safety). – Regulation on rights and duties for persons who are responsible for safety; – Principles of operation; – Equipment, tools used when carrying out works on or in contact with electric equipment. – Measures for ensuring safe works; – Regulation on awards and fines related to implementation of technical safety standards.

No.	Name of document - date of issuance - issuing authority	Contents
2	Decision No.235 QD/LD by MOLISA and State Technical Committee.	Decision on technical safety for steam boilers.
3	Regulation on safety of steam boilers (QPVN 23-81), dated 05-9-1981.	Regulation on safe manufacture and use of steam boilers, including: – Regulations on installation of steam boiler for safe operation – Technical inspection for steam boiler and its parts which are newly installed; – Periodical inspection and hydraulic testing for steam boilers in operation (one time every two years); – Sudden inspection: for steam boiler after one year operation stop; moved to other place or after repairing etc. – Regulation on qualifications of technical staff.
4	Decree No. 06/CP dated 20/01/1995, by the Government	Some clauses of Labour Law on labour safety, labour hygiene.
5	Decree No. 110/2002/ND-CP, dated 27/12/2002 by the Government	Amendments of some clauses in the Decree No. 06/CP by the Government.
6	Circular No. 23/2003/TT-BLDTBXH, dated 03/11/2003 by Ministry of Labour, Social and Invalid Affairs	Regulation on list of equipment and substances related to labour safety, which must be strictly checked and registered (steam boilers with pressure over 0.7 kg/cm^2, water heaters with liquid temperature over 115°C etc.)
7	Interministrial Circular No. 03/2003/TT-BTC, dated 10/01/2003 by Ministry of Finance	Schedule on fee levels for inspection, testing technical safety for machinery and equipment.
8	Electricity law endorsed by the National Assembly on 03-12-2004	The definitions on electricity operations: Obligations of electricity generators in complying with the procedures, standards on operation of power plants, power networks, finding measures for treatment of faults causing unsafe conditions for lives.

No.	Name of document - date of issuance - issuing authority	Contents
		Regulations on safety in power generation: arrangement of power plants, equipment necessary for prevention of fire, explosion, emergency exit system, lighting system, danger warnings etc.
9	The Decree No. 105/2005/ND-CP dated 17 /8 /2005 by the Government	Guidelines on implementation of some clauses of Electricity Law: Requirements for handing over design, technical documents and implementation of testing, commissioning before operation of the project. Requirements on qualifications for individuals whose works are directly related to electricity; Entrusting of duties on electric safety to: Ministry of Industry, Ministry of Science and Technology, Ministry of Construction, People Committees of provinces, cities under management of the Government. Regulation on safety for power transmission (substations, overhead lines and underground cable lines etc.).

Besides the regulations for construction and maintenance of renewable energy power plants different obligations for investment.

4.3.4.2 Obligations to Obtain Permissions

For permission two stages of permission are required the national permission to conduct a project in Vietnam and the permission to invest in Vietnam and to operate business. These two kinds of permission and its obligations are discussed in this chapter.

4.3.4.2.1 National Permissions

In order to invest and construct a biogas power plant on Phu Quoc Island it needs permits from competent authorities.

Vietnam Government issued the Decree No. 52/1999/ND-CP dated 8-July-1999 promulgating regulation on investment and construction of a project on Vietnam territories. The Decrees No. 12/2000/ND-CP dated 05-5-2000, decree No. 07/2003/ND-CP dated 30-1-2003 specifying some amendments for Decree No. 52/1999/ND-CP. Besides, related ministries and sectors issued circulars guiding for implementation of these decrees.

According to the regulation, procedures for investment and construction of projects in Vietnam are as follows:

IV. Investment preparation,

V. Investment implementation, and

VI. Investment finishing, putting the project into operation.

The investment projects are divided into two main types:

III. Projects using domestic financial capital resources (including foreign loan by the government and ODA) and projects with foreign investment capital.

IV. Projects using domestic financial capital resources are divided into 3 groups (A, B and C). Investment levels of projects in groups A, B, C for each production and business categories is various. For projects producing energy (electricity), limits of investment amounts for groups A, B and C are more than 600 billion VND, 30-600 billion VND and up to 30 billion VND respectively (equivalent to above) 37,974,000, 1,898,000-37,974,000 and up to 1,898,000 US$).

Clause 4: Investment and construction procedures

1. Process of investment and Construction includes 3 phases

I) Phase of Investment Preparation

II) Phase of Investment Implementation

III) Phase of Construction Accomplishment, putting the work into operation

2. All the tasks of investment and construction implementation stage could be processed in sequence, overlap or intermixing according to the project's specific conditions and the decisions of investor.

3. Investor has responsibility to recover capital and pay back investment capital.

In phase of Investment preparation, there are 3 important steps:

IV. Writing project investment proposal,

V. Appraising project and Submitting documents for approval,

VI. Project assessment and project investment Decree.

I. Writing project investment proposal

The basic study documents of investment project include pre-feasibility study report, feasibility study report and investment report.

For projects of group B, pre-feasibility report must be prepared only in case competent body for making decision on investment has written request on this report. The projects of group C with investment capital above 1 billion VND (63291 US$) need to prepare feasibility report, investment report. For the projects with investment capital less than 1 billion VND, only investment report is needed.

II. Appraising project and Submitting investment acceptance for Prime Minister's approval

For projects of group A, the pre-feasibility need to be prepared for getting investment license (except those which have been decided for investment by the National Assembly or the government or the project is a component of the bigger project which has pre-feasibility report already approved).

The submitted document for Prime Minister's approval in pre-feasibility study report and investment acceptance contents:

+ Submitted paper for Prime Minister's approval attaches with pre-feasibility study report and investment acceptance Report of Investor.

+ Documents that confirmed legal entity of investor –

+ Plan of project capital mobilizing -

+ Legal documents that related to project site and another legal papers.

III. Project assessment and project investment Decree

Documents of investing appraisement includes:

+ Statement paper of investor applies to investing certificate jurisdiction office (regulated in laws), attaching with final project feasibility report.

+ Project verifying documents and submitted report of investigating office to Prime Minister for investing certification

+ Prime Minister's Investing Acceptance Documents

+ Investigating suggestion of loan banking organization about financial plan, pay back plan, loan acceptance (to project using loan capital)

+ Documents and updated data of compensation, site clearance, resettle plan (in which project had requires for resettling)

<u>The content of Investment Decree includes:</u>

13. Investment Objective
14. Investor Declaration
15. Project Management Form
16. Location: land use area, environmental protection approach, resettle and recover plan (if any)
17. Technology, designed capacity, architecture approach, technical standard and construction level
18. Regulation of national resource exploiting and utilizing (if any)
19. Total investment capacity -
20. Investment resource, financial capacity and capital plan of project
21. Project's Subsidization, Supports from government
22. Project implementation approach. Regulation of bidding package division and the way of contractor selection.
23. Construction time and principal progress stones. Latest time for commencement and completion
24. Relationship and responsibility of relative Ministry, local government (if any). Effective date.

IV. <u>Phase of investment implementation</u>

In this phase, some important content related to certification are: application for land distribution or renting, construction certificate, resource exploitation certificate (if any), appraisement of approved design and total construction estimation, selection of consultative contractor, purchase of equipment and construction material.

During project implementation, if the project is managed directly by the investor manages the Project Management Board has to apply for legal entity. If investor rents another professional organization to manage the project, this candidate has to register for certificate of investment and constructing consultant.

V. <u>Phase of Construction Accomplishment and Construction Operation</u>

After completion of construction work, the commissioning and taking over the project must be carried out, the total cost of the project must be liquidated and the project must be registered as the owner's asset according to the laws.

According to Master Plan approved by the Minister on November 11th 2005, Phu Quoc Island has many advantages in regard to the considered investment and construction. The Project on "Production of Renewable Energy from Organic Waste and Biomass by biogas Plants at Phu Quoc Island" will create many benefits on tourism and subsequently social - economic issues. Because of the economical advantages for the region it was strongly supported by local government at Provincial and District level.

Following the national electricity regulations for feeding power to the regional grid operated by the state owned Electricity of Vietnam (EVN), the investors have to get an agreement with the operator. Before permission, the plant-operator needs to discuss the issues with the Kien Giang's People Committee, Phu Quoc's People Committee and EVN. In November 2005, group of project's experts presented the projects and discussed mitigation and measures with the stakeholders. At the end of the participatory meetings the project got appreciated in consensus of all stakeholders.

4.3.4.3 Summary of the Legislative Assessment

The legislation affecting the construction and operation of the anticipated project is basically determined by the regulations and laws concerning buildings and construction requirements, environment and operational safety. These requirements apply to local as well as international or foreign organisations.

An important point in the building regulations is that qualified staff is required for construction and the main contractor has to have experience and qualification to carry out the work, which tries to ensure building standards and guarantees that cannot be ensured by untrained workers from the informal economy.

Besides the general permissions given by laws and regulations the projects are separated by its investment volume in classes A, B and C and need to be approved by the Prime Minister. Above that all project owners need to submit detailed planning documents to the Ministry of Planning and Investment for assessment. Projects of group A need a pre-feasibility study handed in at the Prime Ministers Office for getting the investment license.

Environmental regulations have high emphasis on water and air quality. Besides that the operational safety is regulated by different laws and decrees reaching from technical safety over labour safety to definitions on electricity operations.

Generally the implementation and the legislative situation as well as the ministerial support of the anticipated project can be seen as very promising because of its consideration as group A project and the Master Plan of November 11th 2005 to develop Phu Quoc Island towards renewable energy use.

4.3.5 Social Impact Assessment

The assessment of the social impact of waste management combined with power and job generation is a complex topic to discuss. Phu Quoc Island's socio-economic conditions such as different economical, social and cultural issues and some anticipated outcomes are already discussed in depth within Chapter 3. Therefore this chapter focuses on the system specific social effects of introducing a solid-state fermenting based biogas production with power generation.

The following sub-chapters discuss the effect on the general employment situation and the safety at work.

4.3.5.1 Employment

A disposal infrastructure including collection, conditioning, combustion and controlled landfilling creates are higher employment compared to the actual situation. It brings employment not only to well educated people like engineers. For the handling of waste also some unskilled labour is needed. This is very important for the 'waste pickers' which nowadays have their income from collecting and make further use of the collected wastes. These people could lose their income when separating the wastes and using them most efficiently. Therefore it is most important to take these weak social classes into consideration and give them appropriate solutions to maintain their living such as waste collection and sorting for money.

4.3.5.2 Health and Safety at Work

While conditioning and combustion needs only little manual turning and maintenance, therefore the safety for workers during the process can be considered as very high. Possible source for injuries is the sorting at the conveyour belt in the conditioning process. Compared to the actual safety conditions of the waste pickers, the organized sorting in the conditioning process is considerably safer.

For workplace safety the workers need to be equipped with adequate personal safety gear according to European standards such as:

+ gloves
+ overalls
+ protective shoes
+ etc.

All transportation machines, especially wheel loaders must be provided with air cleaning filters.

The equipment provided needs to be cleaned periodically to avoid health threats from untreated waste, residing bacteria and fungi. During waste-handling inhalation protection must be used to prevent pulmonary diseases.

Additionally mandatory specific safety training for the facility staff should be conducted periodically and also the collector should be given a basic training for safety awareness. Besides that they also should be equipped with personal protective gear and tools for collection (e.g. bags).

4.4 Option 3: Combined Biogas and Biomass Combustion Plant

The third option was the idea to combine a biogas system with a combustion system in order to exhaust both ways of energy generation. It was thought that it could be suitable for treating the household waste as well as separately collected wooden materials. Wooden materials can hardly be treated in a fermentation process and thus, they could be utilized in a biomass combustion system afterwards or -even better- separately. A flow chart of a suitable combination is shown in Figure 4-32 below.

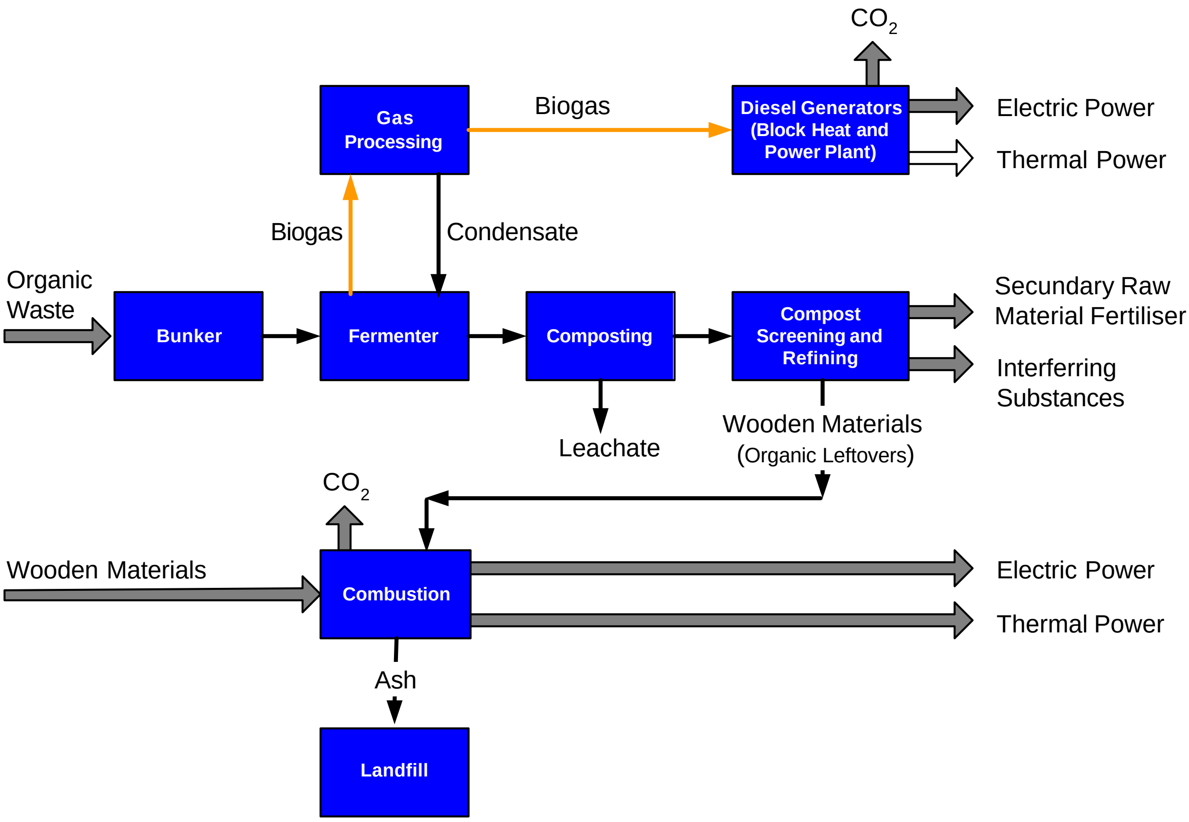


Figure 4-32: Simplified flow chart of combined biogas and biomass combustion processes

While investigating the preconditions of combustion plants, the assessment of a combination was found as follows:

It will not be feasible to implement both plants, a biogas and biomass combustion plant, in combination. The quantity of the output of the biogas plant will not be sufficient to represent the input for the combustion process which needs a minimum amount of input material to run economically. The wooden materials that can be supplied directly are not sufficient enough to be used in addition in order to meet the demand of total input material.

For this reason a profound assessment could be stopped here.

5 Risk Assessment

5.1 Introduction of Risk Assessment

The typical constraints to an optimal use of renewable energy in developing countries are legal and institutional barriers as well as lack of information and technology transfer.[54] In order to help promoting the use of renewable energy in these countries a systematic procedure to decision making processes should be provided to stakeholders involved in energy supply as well as local and regional decision-makers. For this to be fulfilled the tools of Life Cycle Analysis (LCA) and risk assessment are used. Thorough analysis of these tools is presented in this report as well as the results of the assessment of the proposed options for renewable energy production for the island of Phu Quoc in Vietnam.

5.2 Life Cycle Analysis Tools

Life Cycle Analysis takes a systems approach to evaluating the environmental consequences of a particular product, process, or activity from "cradle to grave". By taking a "snapshot" of the entire life cycle of a product from extraction and processing of raw materials through final disposal, LCA is used to assess systematically the impact of each component process.

LCA can be used as a decision making tool between alternative processes compared to conventional solutions. The basic methodology of a LCA is based on 4 steps[55]:

1. Definition of the scope and the subject of the assessment
2. Data inventory
3. Impact assessment
4. Improvement assessment

To date, most LCAs have focused on the data inventory component, as it is the most "objective" (and therefore, least controversial) analysis to perform. In the last decade, several different databases for Life Cycle Assessment (LCA) have been developed which have been extensively used with a number of LCA software allowing researchers detailed analysis of for instance, the distribution of environmental load over world regions.[56]

[54] Food and Agriculture Organization of the UN (1999)
[55] Boura, A.; Moussiopoulos, N. (1998)
[56] Goedkoop, M.; Nijdam, D.; Wilting, H. (2003)

The LCA tool has been used to evaluate the environmental aspects of the project. Several LCA tools such as EcoIndicator, DFE tool, GEMIS, SIMA PRO have been reviewed in order to find the one that combines user-friendly environment, extensive internal energy-oriented database and interconnectivity with other commercial applications. Finally the GEMIS software has been selected to calculate the emissions and the power and material flow for the three options (Figure 5-1). GEMIS is the acronym for Global Emission Model for Integrated Systems[57]. GEMIS is developed by the Institute for Applied Ecology, Germany. The model can perform complete life-cycle computations for a variety of emissions. The GEMIS database offers information on energy carriers (process chains, and fuel data) as well as different technologies for heat and electric power generation. Each and every data item of the core database which covers more than 7000 processes in more than 20 countries including Vietnam can be adjusted. More than 1500 processes concerning bioenergy are available, many of them specifically studied for developing countries. The current GEMIS version covers the data background of a research project concerning biomass use ("Material flow analysis for the sustainable energetic use of biomass"). The results of the analysis will be analyzed thoroughly later on this report.

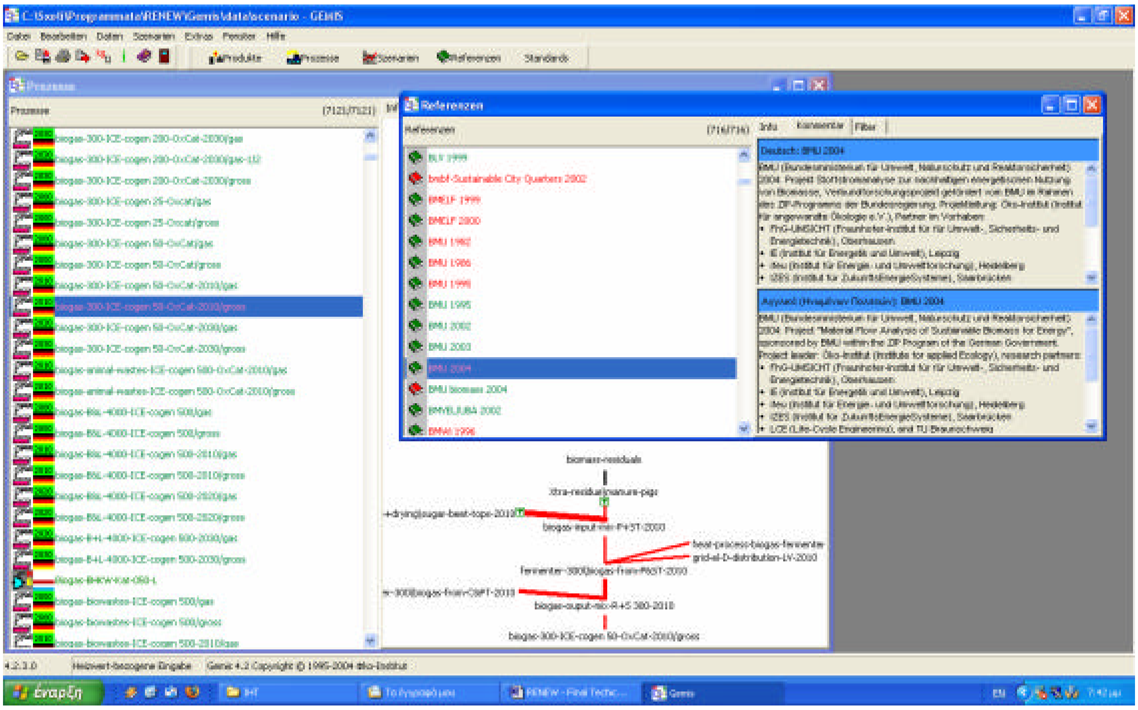


Figure 5-1: The GEMIS software desktop

Indicators for emissions on local and global level have been calculated and will be presented later on this report. Data has been taken both by results of the project BiWaRE and by studies concerning biomass production and local statistics[58].

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[57] http://www.oeko.de/service/gemis/en/index.htm

[58] CAN THO UNIVERSITY (2004) & BiWaRE

These included population inventory, power consumption and installed capacity of the island, growth rates, mean annual per capita waste production, waste composition, biomass production and availability[59].

Specifically the standard procedure for the use of LCA has been followed for each option. The system boundaries have been identified and analysis results have been produced. Most important factors to be taken into consideration are TOPP (Tropospheric Ozone Prevention Potential) equivalents, SO_2 equivalent emissions, CO_2 equivalent emissions, as well as particulates and NOx emissions. Moreover other pollutants such as SO_2, CH_4, CO, Non Methane Volatile Organic Compounds (NMVOC), H_2S, NH_3, as well as airborne As, Cd and Hg emissions are calculated.

5.3 Risk Assessment of Biogas Production / Biomass Combustion on Phu Quoc

Public interest in health and environmental impacts of pollution has grown considerably in recent years due to the increased awareness of health effects of environmental pollution. This interest has made it vital to include the public in the decision-making process. The key advantages of public participation are that important environmental projects are implemented under immense public pressure, expensive and non-effective projects are forced to terminate, and liable polluters are forced to perform necessary cleanup through the litigation process. In order to obtain the best feedback from the public, communication and education of the public are vital. However, communication of risk information is inherently difficult and complex due to the complexity of the technical information. Even in the presence of this difficulty, it is still important to encourage public participation to avoid situations of serious misunderstandings.[60]

Risk assessment is the process of estimating the potential impact of a hazard on a specified system under a specific set of conditions and for a certain timeframe[61].

The risk assessment methodology comprises of hard and soft components. The level of risk can be described:

- Qualitatively or
- Quantitatively.

[59] QUYNH, D.N. (2005) & LIEN, T.K. (2001)

[60] KHADAM, I.; KALUARACHCHI, J. (2003)

[61] HAMMONDS, J.S.; HOFFMAN, F.O.; BARTELL, S.M. (1994)

Current risk assessment methods do not enable accurate quantitative estimations of risks other than public and individual health related risks. Numerical estimation of risks will rarely be feasible because of variability in the agent and population. There are limitations in toxicological and exposure data which will be reflected in the uncertainty assessment. However, a degree of quantification may be possible for some components such as data collection and exposure assessment.[62]

Health risk can be quantified through a risk model that assumes a linear relationship between the intake chemical dose and the risk to individual health. The relationship is based on the coefficient called *the slope factor* in the case of carcinogens, and the coefficient called *the reference dose* in the case of non-carcinogens. Slope factor is the potential of developing cancer for a certain daily dose taken over the lifetime. Reference dose is an expression of the adverse non-carcinogenic health effects associated with high intake of chemicals.[63]

The procedure usually adopted in performing this evaluation, is based on the following:

1. Identification of Chemicals of Concerns (COC)
2. COC Fate and Transport Assessment
3. Exposure Scenario Definition and Exposure Intake Assessment
4. Dose–Response Assessment
5. Risk Characterization.

The individual cancer risk of a receptor *j* set by exposure to multiple carcinogenic chemicals *i* is calculated through the following equation[64]:

$$\text{Individual Cancer Risk}_j = \sum_i \left(LADD_{ij} * CSF_i \right)$$

where:

$LADD_{ij}$ Lifetime Average Daily Dose for a lifetime exposure of 70 years through multiple exposure pathways [mg/(kg*day)]

CSF_i Cancer Slope Factor for COC *i* $[mg/(kg*day)]^{-1}$.

[62] HAMMONDS, J.S.; HOFFMAN, F.O.; BARTELL, S.M. (1994)

[63] KHADAM, I.; KALUARACHCHI, J. (2003)

[64] MORRA, P.; BAGLI, S.; SPADONI, G. (2006)

Comparing an exposure estimate to a Reference Dose (RfD), the potential for non-carcinogenic health effects resulting from exposure to a chemical is evaluated. A RfD is defined as a daily intake rate that is estimated to cause no appreciable risk of adverse health effects, even to sensitive populations, over a specific exposure duration. Generally, the more the Hazard Quotient value exceeds the value 1, the greater is the level of concern. In spite of this, because RfDs do not have equal accuracy or precision, and are not based on the same severity of effect, the level of concern does not increase linearly as the quotient approaches and exceeds the value 1. Based on similar COCs toxicological characteristics and additive health effects, the Hazard Quotient (HQ) for receptor *j* exposed to multiple chemicals *i*, is calculated as[65]:

$$HQ_j = \sum_i \frac{ADD_{ij}}{RfD_i}$$

where:

ADD_{ij} Average Daily Dose averaged for the exposure duration relative to the toxic *i* for the receptor *j* through multiple exposure pathways [mg/(kg*day)]

RfD_i COC *i* Reference Dose [mg/(kg*day)]

A complete environmental and human health risk assessment requires the integration of information on environmental and chemicals database, inter and intra media dispersion models output, site description maps and demographic database. As a result, the designing and conducting analysis of the effects of contaminants on human health is a complex and time expensive procedure, particularly when the aim is to estimate risk in a geographical area characterized by the presence of several sources, exposure pathways and receptor typologies[66]. The estimates of risk for human being caused by human activities is profitably done if the complete procedure of risk calculation can be adopted.

Technology and operational risks are the principal deterrents to the implementation of RE technologies and the sequencing lack in funding. Barriers associated with investment in RE projects are categorized according to distinct but interrelated themes including[67]:

- Cognitive barriers,
- Political barriers,
- Analytical barriers,
- Market barriers.

[65] MORRA, P.; BAGLI, S.; SPADONI, G. (2006)
[66] MORRA, P.; BAGLI, S.; SPADONI, G. (2006)
[67] HAMMONDS, J.S.; HOFFMAN, F.O.; BARTELL, S.M. (1994)

Main risk aspects on the implementation of this project have been identified. They are assessed and presented later on this report. Quantitative classification was not able to be performed due to the qualitative nature of the data, whereas qualitative assessment has been made for each of the aforementioned risks. In decision making, trade-offs should be made between economic considerations, legal liabilities, technical feasibility, uncertainty of the extent of harm to the public and the environment, and finally the ethical considerations and commitments to society's welfare.

Further categorization can be done separating hard and soft risk components. Hard components include technical and physical risks and are associated mainly with the technology selected, while soft components consider environmental, social, political as well as managerial risks and are connected to the specific area conditions where the project is to be implemented as well as the technology selected in terms of environmental impacts. For each risk category different significance is assigned based on special local conditions. Where quantitative classification is not possible qualitative order should be used in terms of low to high risk classification. This provides a tool to local stakeholders to decipher between options presented during the decision making process.

A sound risk-based decision analysis methodology should include the cost-effectiveness of each measure as a justification for implementation. The actual cost of the measures and feasibility should be considered, and the balance between cost and acceptable risk should be maintained. Finally, the relation between the size of the exposed population and individual risk should be considered.[68]

Biomass/Biogas projects, in particular, suffer significantly from resource supply risk and small scale. One issue that comes up repeatedly when seeking finance for biomass/biogas and cogeneration projects is security of fuel supply and fuel price volatility. Crop yield insurance may be a solution where energy crops are involved. But traditionally this cover has been difficult to come by for reasons of scale and non-standard crops. A form of business interruption cover is required as well as instruments to secure long-term fuel supply contracts. However, no such products are available yet. Even a standard business interruption cover can be difficult to purchase because of the length of the reinstatement period for biomass plants which are dependent upon continuity of fuel supply.[69]

[68] HAMMONDS, J.S.; HOFFMAN, F.O.; BARTELL, S.M. (1994)

[69] UNEP (2004)

Machinery Breakdown and Business Interruption insurance is widely available for biogas plants that use tried and tested machinery. For waste to energy plants the technology risk is not considered. It is an issue by many insurers as most of the technology involved is now mature, although manufacturing warranties are still a prerequisite. For biogas plants involving fermentation processes, technology and operational risks are a concern for underwriters as health risks are associated with noxious gases. Without strict safety procedures and operational experience for the technology and operators involved in controlling the fermentation process there are difficulties in obtaining wide coverage[70]. The key risk issues and management considerations concerning biomass and biogas power are presented in Table 5-1.

Table 5-1: Risk management considerations and key issues concerning biomass and biogas power projects [UNEP (2004)].

RE type	Key risk issues	Risk management considerations
Biomass power	**Fuel supply availability/variability.** **Resource price variability.** **Environmental liabilities associated with fuel handling and storage.**	**Long-term contracts can solve the resource problems.** **Fuel handling costs.** **Emission controls.**
Biogas power	**Resource risk (e.g. reduction of gas quantity and quality due to changes in organic feedstock).** **Planning opposition associated with odor problems.**	**Strict safety procedures are needed as are loss controls such as fire fighting equipment and services.** **High rate of wear and tear.**

5.4 Examined Options

5.4.1 Option 1: Biogas Plant

For Option 1, a dry fermentation process is selected for biological waste treatment and renewable energy production[71]. The household waste can be processed in the biogas system without further pre-treatment or separation. The system boundaries for option 1 are presented in Figure 5-2. The system includes the fermentation process itself and also the waste transportation system and the electricity generation process.

[70] UNEP (2004)

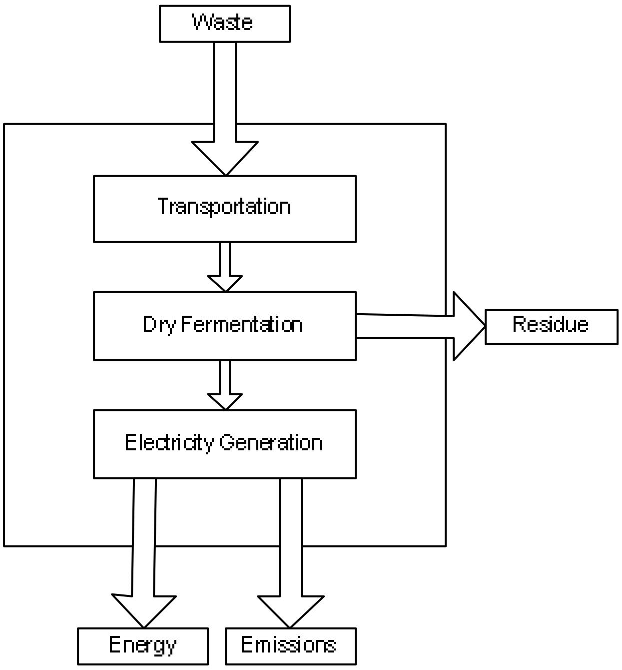

Figure 5-2: Option 1 system boundaries

The daily production of household waste is estimated to the amount of 0,53 kg per capita. The annual quantity of household waste to be treated is calculated to approximately 15,5 million kg. The specific energy demand of the households in the villages ranges between 40 and 80 kWh/month and thus averages 60 kWh/month. The LCA calculations of Option 1 are shown in the following Table 5-2.

Table 5-2: Option 1 emission calculations

Emissions	**g/kWh$_{\text{produced energy}}$**	**Emissions**	**g/kWh$_{\text{produced energy}}$**
CO_2 equivalent	67.071	CO	0.2202
SO_2 equivalent	0.976	NMVOC	0.043914
TOPP equivalent	1.198	H_2S	1.31E-7
SO_2	0.330	NH_3	8.8117E-05
NO_x	0.925	$As_{(air)}$	7.94E-7
Particulates	0.031	$Cd_{(air)}$	5.483E-7
CH_4	0.115	$Hg_{(air)}$	7.463E-7

[71] LUTZ,P.; WITTMAIER,M.(2005) & DALHEIMER,F.; HEERENKLAGE,J.; STEGMANN,R.(1999) & KOTTNER,M.(2005)

The main risks identified on the implementation of Option 1 are:

- Waste collection system efficiency.
- Waste temporary storage that can pose environmental threats.
- Biogas production and handling system that requires strict safety precautions.
- Electricity grid upgrading needed for undisturbed power availability.
- Available funding until the full operation of the plant.

Waste collection efficiency and adequate funding of the plant are considered high risks that can pose serious setbacks during both the projects' implementation and life-cycle.

5.4.2 Option 2: Biomass Combustion Plant

For Option 2, a combustion plant as indicated in the feasibility study is examined. An electrical power of 1240 kW, including the need of electricity for the incineration module is foreseen. The LCA calculation of emissions of the proposed plant are shown in Table 5-3.

Table 5-3: Option 2 emission calculations

Emissions	$g/kWh_{produced\ energy}$	Emissions	$g/kWh_{produced\ energy}$
CO_2 equivalent	486.430	CO	1.280
SO_2 equivalent	11.743	NMVOC	0.21262
TOPP equivalent	17.798	H_2S	0
SO_2	3.633	NH_3	1.325E-08
NO_x	1.167	$As_{(air)}$	2E-11
Particulates	0.164	$Cd_{(air)}$	5E-10
CH_4	0.241	$Hg_{(air)}$	1E-12

Several risk issues are to be addressed for this option to be both environmentally feasible and economically viable. These include

- Annual availability of waste.
- Flue gas cleaning systems have to be ensured
- Waste temporary storage can pose environmental threats and unwanted odors.
- Waste handling system requires strict safety precautions for the personnel.
- Available funding until the full operation of the plant.

5.4.3 Conventional System

Finally, the conventional electricity production system is examined. The system utilizes conventional internal combustion diesel engines for electricity production. The desel engine system equivalent was calculated for comparison with the two studied options.

Table 5-4: Conventional system emission calculation

Emissions	g/kWh$_{produced\ energy}$	Emissions	g/kWh$_{produced\ energy}$
CO_2 equivalent	1278.532	CO	4.1414
SO_2 equivalent	18.312	NMVOC	0.089337
TOPP equivalent	27.091	H_2S	3.597E-09
SO_2	3.163	NH3	6.498E-07
NO_x	21.758	$As_{(air)}$	2.227E-07
Particulates	5.438	$Cd_{(air)}$	1.396E-07
CH_4	0.118	$Hg_{(air)}$	2.646E-07

5.5 Discussion

The comparison between the main emission indicators of the proposed options and the conventional system as calculated with GEMIS software are presented in Figure 5-3 until Figure 5-5.

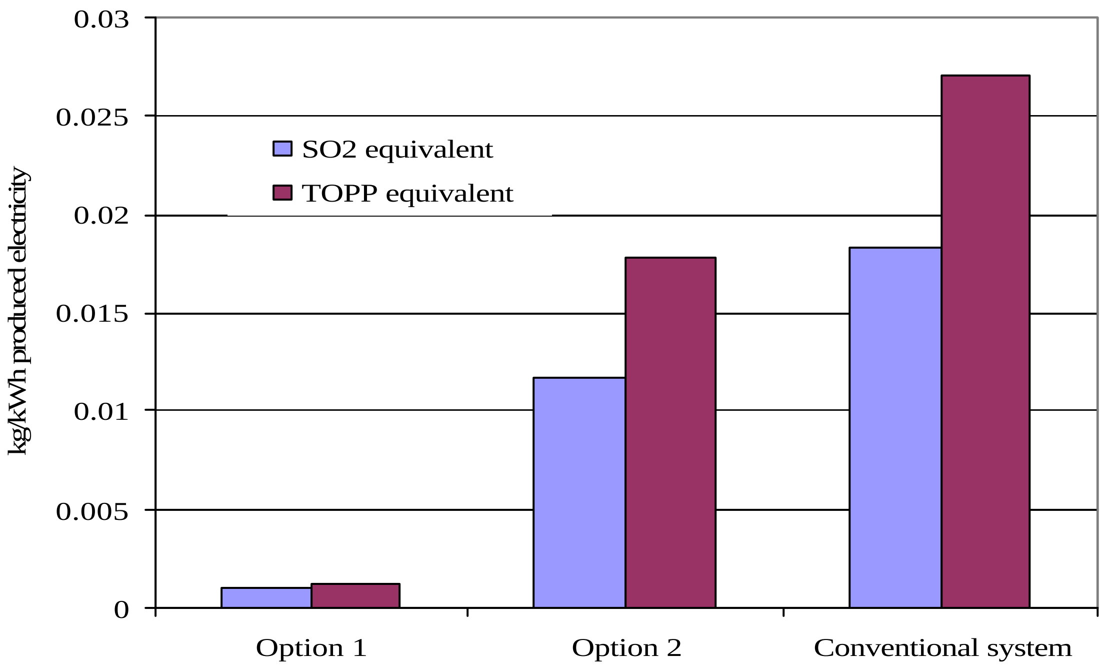

Figure 5-3: TOPP and SO_2 equivalent emissions per kWh of produced electricity for each examined system

The emissions are calculated in kg/kWh of produced electricity or kg/year for the operation of the plant. The presented comparative analysis combined with the risk assessment of each option already presented can lead to decisions according to the specific criteria set by system administrators or local authorities. Moreover, financing issues along with technological barriers to the implementation of each option play a significant role in the decision-making process.

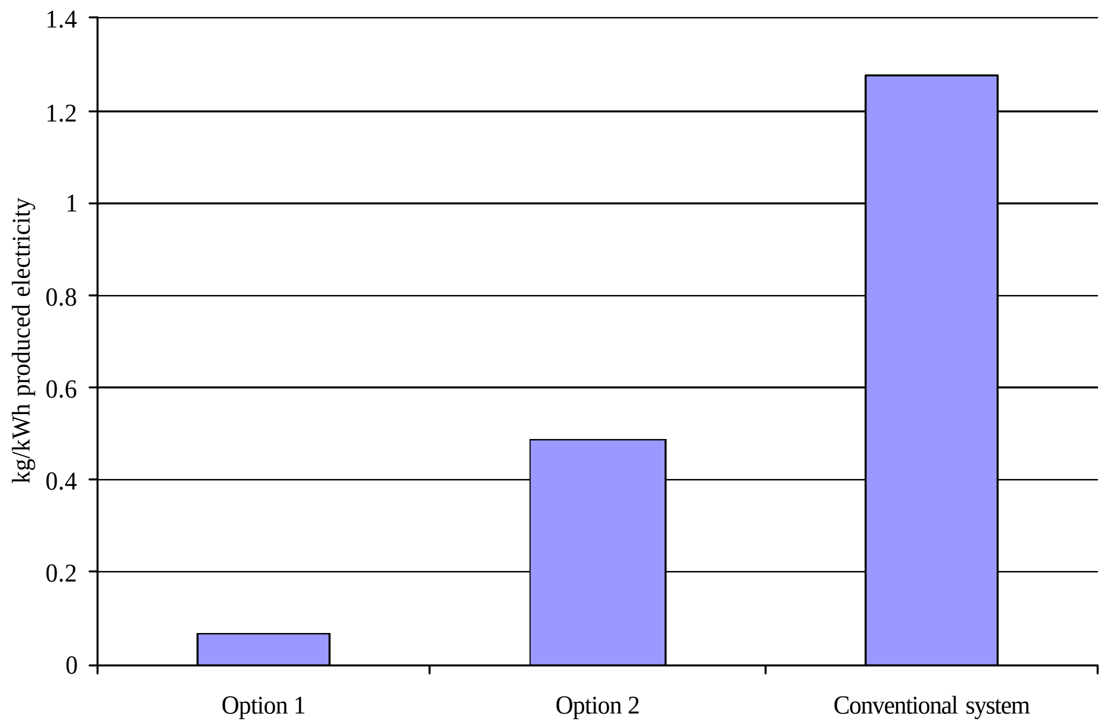

Figure 5-4: CO_2 equivalent emissions per kWh of produced electricity for each examined system

As clearly illustrated in Figure 5-4, the CO_2 equivalent emissions are significantly decreased for both options comparatively to the conventional system. Moreover, Option 1 presents the lowest CO_2 equivalent emission rate adding to the lowest absolute CO_2 equivalent emissions, because of the plant's smaller capacity.

By comparing Options 1 and 2, Option 2 has greater emission rates in terms of kg/kWh of produced energy. However, the absolute emission values are comparatively the same. Therefore economical factors (i.e. costs, payback period) and risk factors (i.e. waste collection, wood availability, highly skilled personnel, and local community acceptance) are to be taken into consideration for the final decision.

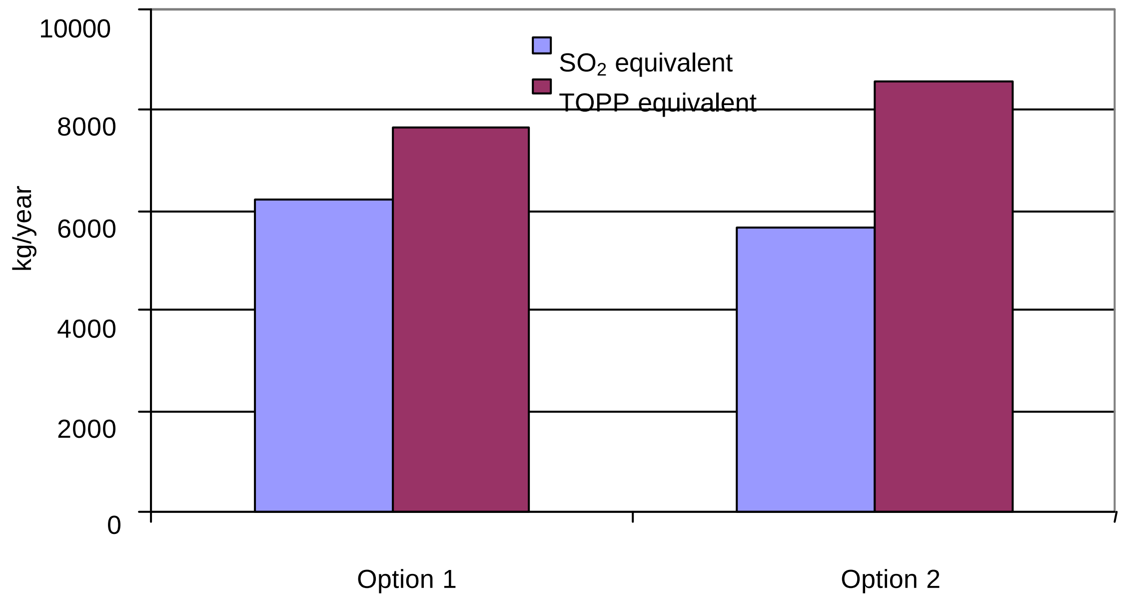

Figure 5-5: Annual TOPP and SO_2 equivalent emissions for the two proposed scenarios

5.6 Conclusion

As analyzed on this report, the decision making procedure for the implementation of renewable energy facilities in developing countries consists among other issues (financial, legislation, social, etc.) of two main elements:

- the risk assessment of each examined option and
- environmental impacts on local and global level.

According to the analysis presented on this report there are several risk issues to be addressed when implementing such a project. The main risk is the availability of biowaste and/or biomass and the capability of the system administrator to ensure stable feed in the facility. Apart from that, as clearly shown in comparison to conventional energy production systems, renewable energy has a significantly lower impact both on local and global level. This combined with the fact that such projects can be used for emission credit trading makes the integration of renewables into the energy grid of developing countries a promising solution. For the specific options examined in this project, it seems that if legal barriers together with financial and financing issues can be addressed Option 1 is the most acceptable choice (taking into consideration the risks that complex systems and the serious health threat to local communities).

6 Comparison of Options Regarding Technology (Option 1, 2 and 3)

6.1 Summary of Project Findings

For the comparison of the options assessed and the decision making for the preferred option all relevant aspects are summarized in the table below. The combination of biogas production and biomass combustion (Option 3) was assessed to be not applicable at an earlier stage of this feasibility study and thus will not be part of the following discussion.

Table 6-1: Summary of project findings

Criteria	Option 1 – biogas plant	Option 2 – combustion plant
Economic aspects (Cost effectiveness)		
Investment costs	3.7 Mio €	5.7 Mio €
Power generation costs	13.4 €-cent/kWh	15.0 €-cent/kWh
Technical aspects (Performance, design, construction, operation, maintenance)		
Ease of construction	Simple construction without major earthworks; simple installation of process components, which are partly pre-installed; no special installation equipment needed	Use of standardized building types (conditioning) possible, compact incineration plant, partly pre-fabricated
Novelty, innovation	high efficiency rate; advanced technology and construction of a well known process; no special pre-treatment of bio-waste necessary	Solar drying is adapted from sewage sludge drying, innovation: high power efficiency

Criteria	Option 1 – biogas plant	Option 2 – combustion plant
Technical aspects (Performance, design, construction, operation, maintenance)		
Flexibility / Stability of process	Good adoption to changing qualities and quantities of substrate; high stability of biogas quantity and quality	The drying process might be influenced by a varying moisture of the substrate input due to the season, major variations in the heat value, especially under the self-sustaining value, of the substrate should be prevented
Adaptability of upgrading	Simple and cost-efficient upgrading by adding of further fermentation boxes and, if rise in capacity is necessary, CHP; necessary equipment can be added easily	No upgrade, a higher capacity can be obtained by a further plant only
Simplicity of operation and control	easy to operate; operation and control reduced to a few main parameters (temperature, gas yield and quality)	Relatively easy, simply structured, no water/steam is needed for the operation
Staffing requirements	trained operator; refilling personnel; personnel to be instructed in health and safety issues	Staff-intensive for manual sorting only
Utilisation of residuals	Secondary fertilizer; dumping	Stabilized – landfilling with no minimized risks

Criteria	Option 1 – biogas plant	Option 2 – combustion plant
Environmental impact		
CO_2-savings	16,700 Mg CO_2 / year	approx. 33,000 Mg CO_2 / year
Area requirements	3,000 m² plus area for expansion	8,700 m² excluding landfill and external infrastructure (supply road)
Odour	No, except during refilling (4 hours)	Yes, from the drying process
Air	Very low emissions due to gas leakage	Low emissions due to the combustion process
Water	No, process runs wastewater free	No water necessary nor arising, the water from the drying process is diluted in the air
Noise	No	No
Legislative aspects		
Permitting requirements	Permission required, well established procedure as there are already existing plants; meets objectives of master plan 2020	Permission required
Social aspects		
Employment	Training and employment of operator, employment of former scavengers for the refilling process	Employment of former scavengers in the controlled sorting process
Health and Safety	Special on-site training needed for all personnel, no H&S impact outside plant	Special on-site training needed for all personnel

6.2 Multi Criteria Analysis

6.2.1 Introduction

The multi-criteria analysis is a tool to determine overall preferences among alternative options and thus support the decision-making process. Complex situations or processes, such as biogas production and biomass combustion, are often connected to multiple criteria which can cause confusion when decision making. The MCA is a structured approach based on the definition of objectives and corresponding attributes or indicators to overcome these uncertainties of the judgement. There are different techniques applicable to carry out a MCA. However all techniques imply the choice and definition of explicit objectives and measurable criteria and the application of scores or relative importance weights.

6.2.2 Criteria for Decision Making

Based on the aspects assessed for each option the following criteria have been defined for the multi-criteria-analysis:

- **Cost effectiveness**: This criterion is considered in most cases and it is often the most important one. For the feasibility study only cost-effective solutions in terms of options have been considered. For the cost comparison investment costs and specific power generation costs (€cent/kWh) were considered.

- **Flexibility and stability of the system:** is a measure of the system`s ability to work under upset conditions or when major changes in input (e.g. change in quality, mass or composition of biomass) occur.

- **Adaptability to upgrading:** considers the feasibility and simplicity of the cost efficient upgrading of the process with regard to all related parameters such as time, costs, construction details, logistics and infrastructure.

- **Novelty, innovation:** considers the innovative character of the applied technology. An innovative process can be used for demonstration purposes and it is especially suitable for realisation within a CDM project. On the other hand the acceptance by the client often depends on the presence of reference plants, which have proven the performance of the technology.

- **Ease of construction:** considers the degree of difficulty, the scheduling and special requirements.

- **Simplicity of operation and control:** The term “operation” comprises all activities to steering the technical process while control comprises the inspection of the system and the assessment of the process operation modes. The simplicity of the operation of a process is characterized by the extent and difficulty in controlling a process, e.g. the need for high level attention or extraordinary staff training.

- **Staffing requirements:** refers to the number of personnel and their skill level. This criterion is of importance if availability of skilled staff is limited.

- **CO_2-reductions (global impact):** The ecological impact of a process expressed by the calculation of CO_2-savings per year is of rising importance. With the assessment of the CO_2-reduction potential the alternative's contribution to climate protection and can be judged.

- **Area requirements:** the estimation of area requirements is an important factor where available space for new facilities is constrained. Also possible area requirements for future expansion should be considered.

- **Odour:** Generally odour affects the plant personal and the community. Although the odour outgoing from a waste treatment facility does usually not have and influence on human health it is a key issue in terms of the public acceptance of the project.

- **Emissions (air):** Generally emissions need control requirements, because they can affect the plant personal and the community. Special control procedures have to be applied for toxic substances. According to modern technical and legislative standards process emissions are an important criterion for permission.

- **Noise:** also affects personnel and community and need control.

- **Water:** This criterion refers to surface and groundwater as sensitive areas, which serve as drinking water source for the community. Emissions from the process (gaseous, liquid or solid) can affect those sources in different ways.

- **Permission:** this criterion comprises the main legislative issues, which could prevent the realisation of the project. Are there permissions required? If so, is the project likely to get permission?

- **Employment:** refers to the employment generation connected to the implementation of a new plant. In detail the number of jobs as well as the diversity of the staff needed (level of skills) is assessed.

- **Health and safety:** considers special precautions needed to reduce the level of risk for the community and plant personnel. Related issues are potential falls, confined space entry, exposed equipment, moving parts, chemical transport/storage.

6.2.3 Application

A performance matrix was used to analyse the performance of both options. Each column describes an option; each row describes the performance of the option against the defined criteria.

For the *individual performance* assessment numerical scores were used: 0 (no performance), 1 (normal performance), and 2 (above average performance). With these three-level scores the performance assessment against the current situation and the relative performance of each option against the other can be assessed. In contradiction to the use of binary terms such as ticks this method is more sophisticated in analytical terms. If we take one environmental impact criteria as example, we find that both options require land for installation and operation of the plants resulting in decreased availability of area. However, the area requirement for option 1 is less than that for Option 2, so Option 1 performs better for this criterion. Therefore option 1 is rated 1 while option 2 gets 0 scores.

In addition the different criteria were *weighted* against each other in terms of importance by using numerical scores on a scale from 1 (least important) to 15 (most important). For example the specific power production costs are an important criterion and thus are weighted with 15 while reduction of noise in comparison is less important and thus is weighted 1. This example represents the maximum range of applied weights. In addition to weighting the criteria against each other, the amount of criteria has to be considered as well. The more criteria defined, the less weight one specific criterion gets. If we take the example of economic factors again, only two criteria have been defined for this “category”, while six criteria have been defined for the category “environmental impact”. If all criteria for environmental impact are weighted 5 while all of “economic” are weighted 10, the environmental impact at all seems more important, which is not the case. Therefore the categories are weighted against each other as well.

By combining the individual performance and the weighting the overall assessment of each option can be calculated.

6.2.4 Results of the MCA

The results of the multi criteria analysis are shown in Table 6-2. All in all 18 criteria from the categories

- Economical aspects
- Technical aspects
- Environmental impact
- Legislative aspects
- Social aspects

were identified to evaluate the feasibility of implementation of a biogas plant (Option 1) or a combustion plant (Option 2).

Looking at the assessed criteria in detail, Option 1 has advantages for the most important aspects and a range of important aspects, as there are

- specific power production costs
- adaptability of upgrading
- utilisation of residues
- permitting procedure (due to well established procedure)

Table 6-2: Results of MCA

Criteria	Weighing of criteria for a renewable energy plant on Phu Quoc	Relative Scoring of options regarding criteria		Results	
		Option 1 (Biogas plant)	Option 2 (Combustion plant)	Option 1 (Biogas plant)	Option 2 (Combustion plant)
Economical aspects					
Investment costs	5	1	0	5	0
Power generation costs	15	2	1	30	15
Technical aspects					
Fexibility/ Stability of process	5	2	1	10	5
Adaptability of upgrading	10	2	0	20	0
Novelty, Innovation	5	2	2	10	10
Ease of construction	1	1	1	1	1
Simplicity of operation and control	5	1	1	5	5
Staffing requirements	1	1	1	1	1
Utilisation of residues	5	2	1	10	5
Environmental impact					
GHG savings (CO2; CH4)	10	2	2	20	20
Footprint (area requirement)	1	1	0	1	0
Odour prevention	1	1	1	1	1
Reduction of air emissions	5	2	1	10	5
Reduction of water emissions	5	2	2	10	10
Reduction of noise	1	1	1	1	1
Legislative aspects					
Permiting Requirements	10	2	1	20	10
Social aspects					
Employment	10	1	1	10	10
Health and safety	5	1	2	5	10
	1 = low weight, 15 = high weight	0 = no performance, 1 = medium performance, 2 = good performance	**RESULTS**	170	109

However, both options have been ranked equally for a range of criteria with different levels of importance:

- Novelty, innovation,
- Ease of construction
- Simplicity of operation and control
- Staffing requirements
- Odour prevention
- Reduction of water emissions
- Reduction of noise
- Employment

Finally, the resulting numbers clearly indicate that the implementation of the biogas plant is the most feasible option.

6.2.5 Discussion and Sensitivity Analysis

6.2.5.1 Influence of Different Scoring Scales

By adapting higher scoring numbers, 1-5-10 instead of 0-1-2, it might be possible to improve the visibility of the difference in the results. Therefore the scores of the relative assessment have been set to 1 (no performance), 5 (medium performance) and 10 (good performance). The MCA was carried out again as described. The results are shown in Table 6-3.

Table 6-3: Results of MCA – varied scoring scales

Criteria	Weighing of criteria for a renewable energy plant on Phu Quoc	Relative Scoring of options regarding criteria		Results	
		Option 1 (Biogas plant)	Option 2 (Combustion plant)	Option 1 (Biogas plant)	Option 2 (Combustion plant)
Economical aspects					
Investment costs	5	5	1	25	5
Power generation costs	15	10	5	150	75
Technical aspects					
Fexibility/ Stability of process	5	10	5	50	25
Adaptability of upgrading	10	10	5	100	50
Novelty, Innovation	5	10	10	50	50
Ease of construction	1	5	5	5	5
Simplicity of operation and control	5	5	5	25	25
Staffing requirements	1	5	5	5	5
Utilisation of residues	5	10	5	50	25
Environmental impact					
GHG savings (CO_2; CH_4)	10	10	10	100	100
Footprint (area requirement)	1	5	1	5	1
Odour prevention	1	5	5	5	5
Reduction of air emissions	5	10	5	50	25
Reduction of water emissions	5	10	10	50	50
Reduction of noise	1	5	5	5	5
Legislative aspects					
Permiting Requirements	10	10	5	100	50
Social aspects					
Employment	10	5	5	50	50
Health and safety	5	5	10	25	50
	1 = low weight, 15 = high weight	0 = no performance, 1 = medium performance, 2 = good performance	**RESULTS**	850	601

Comparing the results it becomes clear that the numbers are higher in total but the relative difference between the two options stays about the same. Therefore it must be concluded that the scaling of scoring does not have an influence on the relative definitiveness of results of the MCA.

6.2.5.2 Assessment of important criteria

Criteria, which are of highest importance, are weighted higher than those that are less important and thus have a higher influence on the result. It is therefore necessary to check whether those criteria have been assessed sensibly. Referring to Table 6-2 the highest result that was generated refers for power production costs, whereas option 1 was scored with a total of 30 points and option 2 with 15. In fact with the dry fermentation processes power can be produced at a lower price compared to the combustion process.

The second important criteria that will be discussed is the adaptability of upgrading, which is important for the future development and thus influences the cost effectiveness of the plant. For the criterion the widest range of the results between the two options was gained. This is due to the fact that the dry fermentation process can be upgraded easily by adding more fermentation boxes to the already existing plant infrastructure while upgrading is not possible at all for the combustion process. Here a new plant has to be established.

Finally, when interpreting the results it must be kept in mind that the choice of weighting scales and relative scores can never be purely objective unless simply numbers are compared. There is always a subjective component when judging. Therefore the MCA was carried out in a team of experts, so that the decisions could be intensively discussed at each stage of the assessment. The clear difference in the total sum underlines the definiteness of the result.

7 Recommendations

7.1 Favourable Option

As result of the assessment it will be technically and economically feasible to implement a 500 kW dry fermentation biogas plant (e.g. BEKON process) with an input of 15,000 tons household waste per year. The energy produced will be sufficient to substitute 13% of the current fossil energy source (diesel). Thus 16,700 tons CO_2-equiv. per year will be saved. Furthermore, the household waste from Phu Quoc will be treated by anaerobic digestion (biogas process) so that environmental damages by uncontrolled waste disposal of untreated waste- the current practice- will be reduced. The solid output of the process will be further treated. A sieved and composted fraction can be utilised as fertiliser. The remaining material is sufficiently stabilised for disposal on a landfill site.

Considering all results, the Consortium finally recommends the implementation of a biogas plant on Phu Quoc Island. A dry fermentation biogas plant, e.g. the BEKON process, will have a number of benefits:

Applicability

- The modular dry fermentation process is more flexible than a combustion plant. It can be adapted easily to increasing waste quantities and changing waste composition to match future developments on Phu Quoc, e.g. due to increasing tourism.
- The biogas plant is operated as batch process and therefore can deal with short-term changing quantities of input material (e.g. small waste quantities in low-season for tourism).
- The type of waste, which will be used as input material, is characterized by high water content and therefore is more suitable for the utilization in a biogas plant.
- Compared to the combustion process, the biogas technology is more adapted to the level of development of Vietnam. Experiences with thousands of small-scale biogas plants, which exist in the Country, are a good basis to operate and maintain a large-scale biogas plant.

Economy

- The biogas plant will require less capital investment than the combustion plant.

Sustainability

- The biogas process supports the recycling of material. A major fraction of the solid output is digested organic substrate, which can be utilized as fertilizer in local agriculture. As a consequence, the import of mineral fertilizer can be reduced and the soil quality can be improved.
- An additional benefit of the biogas plant is, that biogas is produced, which can be directly provided to households or industry, e.g. for cooking.

Acceptance

- It can be expected that the acceptance for the biogas plant will be higher than for a combustion plant. The biogas process is a well- known technology in Vietnam and is implemented with thousands of (small scale) plants.

7.2 Feasibility of Other Options

In addition to the recommendation of the favourable option the feasibility of the other options that have been discussed will be summarized in the following. From the assessment it can be concluded that it will also be feasible to implement a combustion process. A combination of a solar drying process and a combustion plant with energy recovery by the innovative Pebble-Heater technology matches the requirements of Phu Quoc. The solar drying raises the heat value of the input without the use of further external resources and stabilizes it biologically. A pre-sorting process stage improves working conditions and efficiency of the scavengers significantly and excludes unwanted material from the further process. Due to the relatively simple Pebble-Heater technology, the investment is lower than for other technical combustion solutions. An investment of 5.5 million € is estimated. Furthermore, the involvement of local companies in the building process can reduce costs. The transport medium for the heat is air instead of water, which makes the process easier to handle and minimises heat transfer losses. The Pebble-Heater functions as a filter and reduces the emissions of dust, aerosols and tar by 50% compared to other technologies. The electrical efficiency of the Pebble-Heater technology is with up to 30% much higher than for all other technologies set into practice. The electricity output is estimated with about 1.2 MW_{el} for an overall input of 16,000 Mg waste per year. The solid output amounts to about 4% of the input, is biologically stabilised and free from smell. No wastewater is produced.

The combination of the two technologies cannot be recommended due to lack in applicability. Even if material flow separation is applied, so that the wooden materials are combusted directly while the bio-waste is sent to the biogas process in the first stage, the quantity of the fermentation residues together with the wooden material will not be sufficient to represent the input for the combustion process, which needs a minimum amount of input material to run economically.

7.3 Recommendations for Project Development

Following the recommendation of a favourable and feasible option, this part will pay attention to the steps needed for the actual implementation of the project. The following steps need to be taken for the realisation of the project:

- planning preliminaries and the outline of the project as well as the implementation
- project approval procedure
- bidding phase including the publication of a call for bids, comparison of the submission and award of the contract
- manufacturing and delivery of the plant and building parts
- assembling of the plant, start of the trial operation, checking of the operation process and instruction operational staff

Parallel to the realisation of the project the future conditions of operation of the plant need to be outlined. This means that the roles of the different project partners, like the operators of the plant, the buyers of the heat energy or electricity and the deliverer of substrates, need to be clarified and the rights and responsibilities have to be written out in contracts.

During the approval process it is advisable to publish the plans for the public to express their interest or concerns about the future development. In some European countries this is a necessary procedure.

The role of the project management is to oversee and organise all the different steps mentioned above. At the heart of the organisational effort required are several plans which will aid the project management with their tasks

7.3.1 Time Plan for Project Realisation

This time plan includes the steps mentioned above in detail with respect to their proposed time of realisation and serves as a check list for the project management.

7.3.2 Check List for Milestones or Project Deliverables

The milestones are extracted from the time plan as the most important deliverables of the project plan.

7.3.3 A Financing or Cost Management Plan

This plan is orientated around the milestone and time plan, listing the estimated costs for each part of the project process. The financing of the project goes hand in hand with the contract that is awarded to one bidder. The financial roles of other persons is also defined (this is strongly interlinked with definition of roles and responsibilities of persons).

7.3.4 Definition of Role and Responsibilities of Persons Involved in the Project

Depicted in a list this information is easier to oversee. It helps for example to keep track of who is responsible for which part of the project and also to organise which partners to address if new issues arise.

7.3.5 A Plan for the Technical Process and Progress

During the supply, assembling and operational phases of the project development a technical process plan, including aspects such as development and maintenance, serves as an addition to the time plan with focus on the technological part of the project only.

7.3.6 A Risk Management Plan

This plan identifies and quantifies the risks that can arise during the project implementation it might also including a risk response plan and a safety plan (see below for more details).

There are several other plans which can be developed to aid the project management. The team of organisers has to decide what quantity and quality of plans and lists in addition to the ones listed above will be helpful for their project. Other plans that are hidden in the above plans but can be extracted if one wishes to do so are for example a scope management plan or a plan for reporting and communication. Sometimes the huge organisational effort coupled with all these plans is comprised in one plan which lists the plans and their purposes.

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