The potential of using biogas at the Roskilde Festival

A 5th semester project by: Group 411
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Foreword

The following project has been developed in cooperation with the Roskilde Festival, in particular with their climate coordinator; Thomas Niebur who contacted the university search for inspiration and input on how to improve the environmental situation on the upcoming festival. The requirements of the festival management, their responsibilities towards their guests and their economic possibilities, has therefore played an important role in the search for the most feasible proposal.

The aim of the project is therefore to serve as an inspiration for the festival management.

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1. Problem field

The Roskilde Festival in Denmark has through 37 years manifested itself as one of Northern Europe's most visited festivals. The crowd has grown from 10.000 to 100.000 visitors through the years and the festival now carries on for 7 days instead of 2. In 1971 20 orchestras performed on 'the stage', and today over 200 orchestras strikes up on 8 independent scenes entertaining, not only those living in the proximity of Roskilde, but visitors from all over Europe. The same is the case for the bands, which now fly in from all over the world to give concert on the Roskilde Festival (Festival, 2008).

During the 7 days the festival lasts, Roskilde Dyreskueplads is thus transformed to the 5th largest city in Denmark. A fact which surely pleases any organizer, but the consequences of such an allocation of people is severe, seen from an environmental perspective. Not only the transport of visitors, and performers, travelling from all over the world, imposes an enormous impact on the environment, but also the amount of energy needed to keep the music playing and the cooking and bar facilities running for 7 days in a row, not to talk of the waste generation from 100.000 people living on campsites, eating and drinking from disposable tableware every day. It is easy to oversee the environmental impact big festivals impose on the environment, but today Europe alone houses over 30 festivals the size of Roskilde[1], witnessing a growing need for environmental management on the increasing number of European festivals.

1.1 Problem Area

As mentioned above, the environmental problems resulting from the festival are numerous, however some problems seem to be more obvious looking at the numbers concerning the extremely high waste disposal and the huge energy consumption of the festival. Within these 7 days, the festival operators calculated a total amount of 3,000 tons of waste within one week, 40 kg per person. Not included is this number, is the manure from 100.000 guests which puts an enormous pressure on the local sewage system (Roskilde Festival, 2008).

The energy consumption needed is approximately 423,000kwh (Corr. with Thomas Niebur). A striking aspect in regard to energy consumption is the 21,324 liters of diesel used on top of that to

[1] Ex. Sziget Festival, Budapest (50.000 visitors), Oxegen Festival, Ireland (80.000 visitors), Pukkelpop, Belgium (100.000 visitors), Hultsfred Festival, Sweden (25.000 guests), Rock Werchter, Belgium, Provinssirock Festival, Finland (70.000 visitors), T in the Park, Scotland (40.000 guests), Benicassim Festival, Spain (60.000 guests) etc. etc. (Crislip, 2008)

run the 15 diesel generators in the camping and cooking areas (agoras) (Ibid). The resulting CO2 emission from this constitutes 56895,32kg CO2[2] released into the atmosphere.

Even though the Roskilde Festival tries to take their environmentally responsibility serious, the problem of the diesel generators and the huge waste generation is still to be dealt with. Therefore the problems we wish to work with are the large amount of waste generation and substituting the diesel generators to reduce CO2 emissions. Both waste generation and diesel emissions play a major role in the polluting of the environment.

1.2 Problem formulation

This leads us to the following problem formulation:

What is the potential in using biogas to reduce environmental impact on the Roskilde Festival, and what other alternative energy supply can be proposed?

1.3 Sub questions

1. How is biogas generated and is it possible to reuse the waste, including the human manure, from the festival to produce it?
2. Is biogas a
    a. realistic and feasible solution which
    b. can solve both the problems of waste production and energy consumption
3. Can biodiesel substitute the diesel?
    a. Is it technically possible and economically feasible?
4. Is wind or solar energy a better alternative energy system to work with?
    a. Is it possible to use wind or solar energy?
    b. What are the prospects and constraints in relations to biogas?

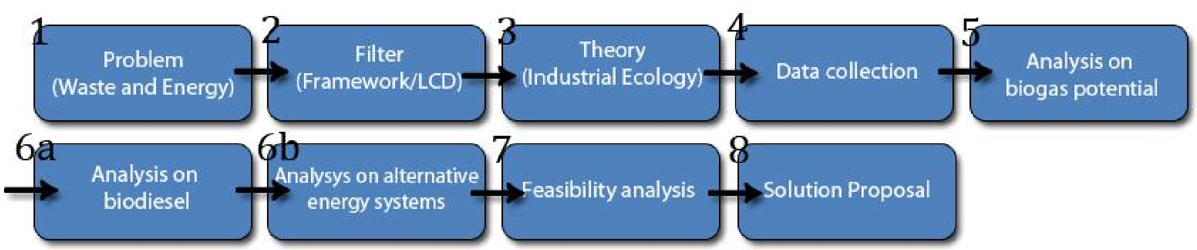
[2] CO2 emissions from a gallon of diesel = 10.1 kg/gallon (U. S. Environmental Protection Agency)

2. Methodology

The purpose of this section is to establish a general overview of the projects methodological deliberations, as well as considerations concerning constraints and possibilities in regard to the projects method.

2.1 Project design

Below is the project design, which purpose is to give the reader an understanding on how the project is structured. The choices we've made will be elaborated on in the further reading of this chapter.



Here follows a short introduction to the above figure.

1. The problem field has elaborated on the environmental impacts in regard to the festival, which among other things[3] are high waste generation and high energy consumption from fossil fuels.
2. We have chosen to work with an actual case; therefore we need to take the whishes and requirements of the Roskilde Festivals management into consideration as well as the environmental needs. If we are to make a difference with this proposal the suggestion needs to be accountable to the wishes of the management, which include economy, performance, responsibilities etc. We've found the methodological approach presented in Keoleian and Menereys (1993) model on Life Cycle Design (LCD) applicable to our project in this regard.

[3] It is very likely that the festival also impose a huge impact on the ground that is possess and that it also inflicts other areas in regard to environment. But in this report we will only focus on waste generation and resource use from the diesel generators, as we see those areas most feasible to work on, in relation to achieving the biggest gain for the festival.

The methodological framework presented in the LCD, will thereby function as a filter on what is actually possible.

3. To understand ways of dealing with environmental problems, we have chosen Industrial Ecology, as this concept has a holistic system view on coping with the environment which we find useful when working with overall environmental impacts from the waste generation and energy consumption on the entire festival area.
4. When determining which areas to work with it is furthermore necessary to establish an overview on where the biggest environmental problems are in regard to waste and energy flows. This will be presented in a flow sheet, where the aim is to identify the amount of waste generated and the amount of energy needed.
5. This will give us the opportunity to continue to work with the potential of using biogas as an energy source.
6. However. To establish a reasonable view on the potential in biogas, we have found it necessary to make a general comparison with other energy friendly solutions. The possibilities we will look into in regard to substitute the diesel generators are biodiesel, wind- and solar energy.
7. This enables us to make the final feasibility analysis, where we will be able to look into both environmental benefits, as well as cost effectiveness, where the latter is considered in regard to whishes and possibilities of the management.
8. The methodology above will now enable us to come up with a proposal for a solution applicable on the Roskilde Festival.

2.2 Overview of the research structure

Below is the Project Design which has the purpose to provide the reader with an overview of the outline of this report.

Table 2.2: Project design

Research question	Sub questions	Method
What is the potential in using biogas to reduce environmental impact on the Roskilde Festival, and what other alternative energy supply can be proposed?	1. How is (a.) biogas generated and (b.) is it possible to reuse the waste, including the human manure, from the festival to produce it?	(a.)Research in anaerobic digestion. (b.) prospects and constraints in using human manure for energy production
	2. Is biogas a: (a .) realistic and feasible solution which (b.) can solve both the problems of waste production and energy consumption	LCD (a.), Industrial Ecology (b.)
	3. Can biodiesel substitute the diesel? (a.) Is it technically possible and (b.) economically feasible?	(a.) analysis on biodiesel and (b.) cost comparison.
	4. Is, wind or solar energy a better alternative energy system to work with? (a). Is it possible to use wind or solar energy or a combination? (b). What are the prospects and constraints in relations to biogas?	(a.) investigation of solar-, wind and hybrid energy systems. (b.) advantages and disadvantages in comparison to biogas.

2.3 Choice of theory and theory outline

The task in this project is to find a theory or concept which will help finding a more sustainable solution for the Roskilde Festival in relation to waste and energy consumption. There is a variety of concepts introduced in this field which could help us understand how to improve the environmental situation and therefore a choice of which concept is most suitable to our problem field is inevitable.

The advantages of Cleaner Production (CP) in contrast to the old concept of pollution control are obvious when looking at the different approaches and initiatives each of them take. The most apparent advantage is that CP aims to prevent any kind of pollution in the first place so further treatment is not relevant. The environmental benefits are obvious, as for instance less waste or less raw materials take the pressure off from natural systems, while end of pipe regulation accept that environmental damage is done, and then aims to control it when the damage has already taken place. This furthermore saves of money and investment in ‘end of pipe’ measure, as they are no longer necessary (Fatta, et al., 2002). Therefore CP can as such be regarded as the more advanced step into a sustainable festival than the traditional approaches of handling pollution after the discharge has already taken place.

In the 'Cleaner Production of Process Industries' Berkel (2000) suggest three levels to work with environmental management in. 1.) The Micro-scale, which is about molecular interactions – also known as 'green industry', 2.) the Meso-scale which is concerned about chemical manufacturing processes and coincide with Eco-'Efficiency' and 3.) the Macro-scale which deals with the flows of materials in the industrial economy, with the purpose of identifying improvement opportunities. This is also referred to as Industrial Ecology (Berkel, 2000). The Macro-scale is therefore the most convenient area for us to work with, as we want to look on the overall possibilities for improvements on the festival area, and not on a specific product or process.

In this paper Cleaner Production is not seen as the overall concept, but rather as a subset of Industrial Ecology. This concedes with the view presented by Basu and Zyl (2004) and Garner (1995). CP is as such only a step towards achieving the Industrial Ecosystem approach found in IE, and ultimately reaching the goal of sustainability. We are convinced that a macro perspective is necessary to identify the most beneficial solutions in relation to the reduction of environmental impacts. Furthermore, the Roskilde Festival has already been working on pollution prevention for a long time, which is why we find it more feasible to take the next step and look into system solutions. Therefore we believe the system approach in IE, to be the most efficient to reduce anthropogenic environmental impact on the festival.

Industrial Ecology follows the holistic flow of materials. From raw-material acquisition to waste disposal. The most prominent tool in this holistic approach, is as such Material Flow Analysis (MFA). Though MFA's it is possible to address where it is most efficient to reduce environmental damage. Industrial Ecology is thereby a way of indentifying which products and process are responsible for the majority of waste generation and energy consumption. The next step is to determine whether the waste from one sector can be used as a raw material in another sector. This exchange of waste, by-products and energy is what is often referred to as an 'industrial eco-system' or 'industrial symbiosis' (Berkel, 2000).

Industrial Ecology thereby constitutes our understanding on how to deal with environmental damage in relation to the project and how we will approach the solution design. Below we want to make a brief overview on possibilities and constraints concerning this concept.

2.4 Delimitations and constraints

Despite the effort to include all relevant aspects into the project report, certain limitations need to be recognized. In this report, the focus has been on the negative effects of diesel pollution and waste disposal, when in fact other environmental impacts from the festival operations have been left out. Impacts such as noise and visual disturbances have indeed an impact on the local city and its inhabitants.

The construction of the 7 stages, the guests which are attending the concerts and the big number of campers and tents have an inpact on the environment as well. This is significantly apparent in the destruction of the soil on the festival area and the impact the festival impose on the trees, plants and wildlife living in the area. These aspects have not been mentioned in the report.

The stages and stages areas take their energy from the grid. As the percentage of renewable energies present in the grid connection in Denmark is already 28,5% (Energinet.dk, 2008), the focus has been on substituting the diesel generators which is, in our opinion, one of the most damaging effects on the environment from the festival. This is why the project focuses on substituting the diesel generators which are mainly used in the camping and the cooking areas, thereby leaving out the stages which are powered by the grid.

Establishing an energy reduction plan for the festival areas in addition to the diesel substitution would have been an effective contribution towards a more environmentally friendly festival. Even though the establishment of such a plan is not the scope of this project, it could contribute positively to the project. Alternative solutions proposals which are suggested in this project would be more accessible and less cost intensive, due to the lower amount of energy which would need to be substituted.

2.5 Generalisability

Even though the ideas developed in this report are meant to serve as a tool for the Roskilde festival management can other big festivals also gain inspiration from the solutions proposed here as they are likely to face the same basic environmental problems than Roskilde. Furthermore other festivals might have other financial possibilities being able to make long term investments, as they might not be obliged to donate their profit to charity like the Roskilde Festival.

It can furthermore be argued that all outdoor activities in which diesel generators are of use can gain knowledge on the alternative energy source available to substitute diesel and thereby reduce emissions.

3. Methodological Framework presented through LCD

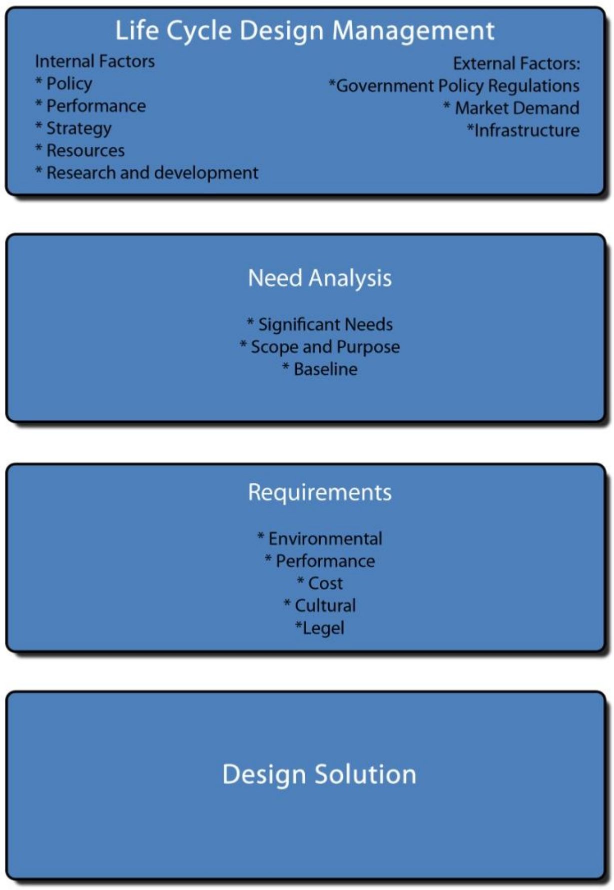
Before starting the writing process, important decisions and methodological approaches need to be made, to address the most important problems and to take the most relevant aspects into consideration.

In order to find a suitable framework to work with, the group found the inspiration in a system oriented approach which is also used in Life Cycle Design (LCD). LCD is a concept which "*seeks to minimize the environmental consequences of each product system component: product, distribution and management*" (Garner 1995, 21). LCD aims at integrating environmental requirements into the product development and product design process.

Even though this principle complies with the aim of this project, the concept itself is not relevant when working with the entire festival area, as individual products will not be analyzed in their life cycle. Therefore *only part of the LCD theory will be used*. Before starting a LCD, there are a range of important aspects and decisions that are proposed, and internal as well as external factors provide a solid starting point for building a strong analysis. The idea is to incorporate the demands of the management and customers in harmony with environmental needs, so that equilibrium between all interests is reached. This strategy is of importance for us, as we wish to integrate all relevant aspects into the analysis and not only to focus on the most feasible solutions for the environment, but to focus on a solution which also suits the guests and the management.

When using this strategy, we aim to obtain a realistic framework of the entire Roskilde Festival complex and how different instances and areas are interconnecting with each other. Any proposed environmental solution needs to lie within the framework of the festival management's- and the festival guests' requirements. The project's framework will orient itself on the figure below, focusing only on the main steps, the management, needs analysis, requirements and design solution.

Figure 3: Life Cycle Design



Source: Garner (1995)

3.1 Design Management

The following passage will explain the theoretical framework of this project. Life Cycle Design will serve for this purpose, but only a little part of the theory will be used to highlight the most important factors for the festival management in their solution criteria. What is meant is that certain needs and requirements need to be met which are indispensable to keep the festival running. It is important to detect the factors that are relevant for the management when searching for the most feasible solutions in the environmental problems that concern the Roskilde Festival. These factors will be divided up and sorted so the most important ones will be filtered out according to the festivals own statements on what the festival revolves about.

3.1.1 Performance

Performance is one of the key aspects for the management. The entire festival revolves about music and creating a memorable performance for its guest. Providing them with the newest technologies and newest music is an essential part for a successful festival operation.

> *"Roskilde Festival's main focus is music – both in terms of quality and style. Every year more than 170 acts play on the festival's seven stages – Orange Stage, Roskilde Arena, Roskilde Odeon, Roskilde Cosmopol, Roskilde Astoria, Roskilde Pavilion and Roskilde Lounge." (Roskilde Festival, 2008 s. 6)*

The festival is known for having excellent light and sound systems, and the aim is that the music shows create unforgettable memories for the guests who will make them want to come back next year. This aspect needs to be recognized, as any attempt to reduce the energy consumption on the sages could easily result in a compromise for the music performances and on the guest which have paid a big sum of money to see the show. A solution needs to be found which does not hinder the operator's main strategy which is to be one of the top festival providers in northern Europe.

> *"There is music from almost all conceivable genres from all over the world, and Roskilde Festival makes a virtue of presenting music that meets the audience's high expectations, whether this includes contemporary stars, legendary bands, trendsetters, innovators – or combinations of all these."- "The audience are curious, and the festival presents music they do not always know in advance, but which offers a memorable experience and an appetite for more. Such musical surprises and insights into the trends of tomorrow– combined with the big stars delivering the communal experiences – attract the largest international audience in Europe year after year." (Roskilde Festival, 2008 s. 6)*

But festivals are not only about music. The guests have certain needs and the management tries everything to fulfill these needs and make the festival a unique experience. Food and drinks play an essential part when being at a festival for one week and good quality food helps creating a positive atmosphere.

> *"Roskilde Festival has developed a food policy through which the offers from the food stalls are continuously strengthened with assistance from professionals from the catering business. Focus is on the individual festival-goer's possibility to choose according to taste – from vegetarian and organic to fast food etc. – with offers from cultures from all over the world." (Roskilde Festival, 2008 s. 7).*

To be able to choose between different types of food is a consumer demand which needs to be recognized when making changes in the food sector.

3.1.2 Resources

The festival's resources constitute another important factor, which aims at identifying possibilities the management has towards changes and new technologies. Roskilde Festival is unlike most companies, because it donates the majority of its revenue to charity. Therefore their budget is limited and yearly revenue is either spent on the festival operation itself or donated to humanitarian work. Therefore, an investment in expensive technologies is not possible like in other companies, as the festival cannot plan on using the money to pay back expensive equipment acquisition. This is an important aspect when looking for feasible solutions as new technologies with long payback times are not the best option for the management. The total working budget presented by the festival management is 120 million kr. each year (Appendix 1).

> *"The charity organisation behind Roskilde Festival is called Roskilde Festival Charity Society. The profit from the annual Roskilde Festival is donated, without any deductions, to this organization which supports transnational humanitarian, cultural and non-profit purposes. Throughout the past 36 years, the Roskilde Festival Charity Society has donated more than DKK 100 million (approx. € 13.5 mill.) from Roskilde Festival to e.g. Support the War Victims in Iraq, Doctors Without Borders, Amnesty International, Save the Children, World Wildlife Fund (WWF) and many, many others." (Roskilde Festival, 2008)*

This delimits the possible solution proposals, as costly technologies with long payback time can already be excluded as all profits made will be used as charitable donations and can therefore not be used to invest. This is a relevant aspect in finding the most feasible solutions.

Entry tickets for the year 2008 peaked at 1475 Danish crowns per person, which is the highest price 36 years (Roskilde Festival, 2009). As Roskilde Festival is indeed not the only festival competing for the European guests, competitiveness plays a major role. If expenses for the festival get to high and tickets prices get even more expensive, some guest might chose to attend other, cheaper festivals in the future. New technologies or environmental projects therefore need to be within the management's budget and not compromise with their ticket prices, as it might exceed their price tolerance.

An important aspect is however that the festival has a climate theme this year and an increased expense in promoting this, for instance investment in reducing CO^2 emissions, is acceptable by the management as long as it advertises the theme (Corr. Thomas Niebur).

3.1.3 Green Image

Not only is Roskilde Festival one of the biggest festivals in Europe, it was also one of the first to develop a form of environmental plan and started as such early in the fight against pollution. Their mission is to demonstrate that the festival takes initiatives to prevent pollution. For example initiatives were initiated last year to collect all used sleeping bags and tents after the festival for homeless people in Copenhagen. Another initiative is that all posters are made of recycled paper and no flyers are allowed to conserve the environment of the festival area. In January 2008 the Festival will received the Green World Award for taking environmental initiatives throughout the past years (Roskilde Festival, 2008). This environmental friendly view needs to be demonstrated to the guest as it is an essential part of the management's mission to promote itself as a green festival to the young audience.

Taking off the pressure from the environment in forms of waste minimization, lower diesel emissions and alternative energy supply will stand in the center of any solution proposal as it is the environmental protection that is the top priority in this project. Indeed, it can also be stated as one of Festival's top priorities:

"Roskilde Festival is an environmentally conscious festival and the aim is to be as environmentally sustainable as possible. Use of resources must be reduced as much as possible and environmental-friendly products must be used when technically and financially possible and to the extent that they do not cause any health hazard. Also, the festival aims at a maximum level of waste recycling" (Roskilde Festival, 2008 s. 7).

The festival has a number of volunteers which are responsible for collecting waste and plastic cups on the festival area for a clean atmosphere. The Festival has its own environmental group which consists of volunteers who are analyzing the existing efforts and presenting recommendation on how to improve the overall situation. Despite all these efforts, areas still exist which need some kind of improvement.

The diesel generators which are mostly used in the camping areas of the festival where grid connection is not easily accessible provide a threat to the environment and the festival guests in forms of CO2 emissions. Therefore any substitution for this form of energy generation is an important aim. The huge amount of waste is another environmental threat which needs to be dealt with. Waste reduction or recycling of the waste will bring benefits to the festival environment and is therefore an important requirement. High energy consumption might be an inevitable factor due to big lighting and sound technologies which are needed at the stages. However any form of lower energy consumption or reduction would be a positive contribution in the fight against pollution if it is possible. The main focus will be on substituting the non renewable energies of grid connection and diesel with alternatives energy systems or technologies. The best option in regard to preserving the environment would be a self sustaining system (Industrial Ecology) where the festival provides itself with renewable energy maybe in forms of waste recycling and therefore will this ides be incorporated as much as possible into the solution proposals.

3.2 Needs Analysis

In this section, all the needs of the festival and its guest will be highlighted to provide the reader with a materialistic framework which is needed to keep the festival running. Here the project scope will be defined for the reader, which includes consumption of beverages, food, energy and water and waste production at the entire festival area.

3.2.1 Energy

Being a festival, the main obligation is to provide the guests with music and light shows. Therefore is energy supply a significant need and without it, the festival would not work. Food and beverages stands are also dependent on energy supply. Therefore energy and electricity is the most important need when supplying 100,000 guests. Due to its 7 large stages, the energy consumption is very high. The collective energy consumption for one week is ca. 423.000kwt (Corr. with Thomas Niebur). Any change or solution proposal has to take into consideration that in light and sound might result in financial losses in forms of unsatisfied customers. The energy comes from two different sources: grid connection for the stage areas and diesel generators for the angoras[4]. The diesel generators need approximately 21,243 liters in one week (Corr. Thomas Niebur).

3.2.2 Beverages

Having enough to drink during the festival is one of the top priorities of the guests and the operators. Without cold drinking goods, nobody will last long, especially considering that it takes place in July where the weather is usually very warm. Beer is the number one beverage at the Roskilde festival and in 2008 the guests consumed a total of 1,000,000 beers. Depending on the weather and the number of guests, this number might even rise in 2009. This results that the festival needs at least a total of 804,000 beer cups, plus 308,000 coffee cups and 304,000 soda coups to meet the crowd's needs (Appendix 1).

3.2.3. Food

Everybody gets hungry so having enough food for the guests is one of the top priorities and they have a variety of food stands to chose from. In 2007 the festival guests used: 851,000 napkins, 347,000 forks, 189,000 knives, 127,000 soup plates, 191,000 plates and 391,000 paper pockets for burgers (Appendix 1).

3.2.4 Water

Without water supply, nothing works, and it is essential to operate a festival in the middle of the summer. Due to its large size and the big number of guests, the festival area consumes

[4] The festival is divided into 8 angoras, which is each in relation to a camping area. Ex Angora J, relates to campingarea J. An Angora is a service area and consists of many different services. Ex. baths, bars, small amateur stages, sales of food and liquids etc.

approximately a total of 10 million liters of water during the one week to meet the needs of food, drinks, sanitary arrangements, cleaning etc. (Appendix 1).

3.2.5 Waste

With such a large crowd and with the amount of food and beverages presented before, the waste disposal of the festival is tremendous. The operators calculated that each festival guest consumes approximately 5 Kg of waste per day and that each one leaves about 40kg behind when they go back home. The total amount of garbage is 3,000 tons, of which 90% is flammable (Appendix 1).

3.4 Solution Design

When summarizing the above mentioned needs and requirements it becomes clear that any proposed solution will have to incorporate a variety of factors and interests. However this challenge seems inevitable when pursuing the most feasible solution for the management, the guests and the environment. The table below demonstrates the complexity of finding a solution which is feasible for all areas of the festival, the management and the environment.

Category	Key aspects	Solution design	Most Feasible solution
Design Management	Performance ------------------------ Competitiveness ------------------------ Consumer demand	Promote Festival ------------------------ Economic benefits ------------------------ Satisfied guests	?
Needs Analysis	Beverages Food Water Energy	Festival operation. Meet needs of festival guests	
Requirement	Environment ------------------------ Costs	Waste minimization Pollution prevention ------------------------ No long payback time	

3.5 Summary

The chapter presented the theoretical framework of the project. The LCD highlighted the most important aspects which need to be incorporated in the search for a better solution. The management has internal and external factors, such as performance and a mission, competitiveness and consumer demands that need to be met. The need analysis provided an overview of the different elements which are inevitable to keep the festival running and which cannot be dispersed. Together with the environmental requirements of less pollution and waste minimization, and the economic requirements, the solution proposal need to incorporate all the above mentioned factors to be feasible.

4. Industrial Ecology

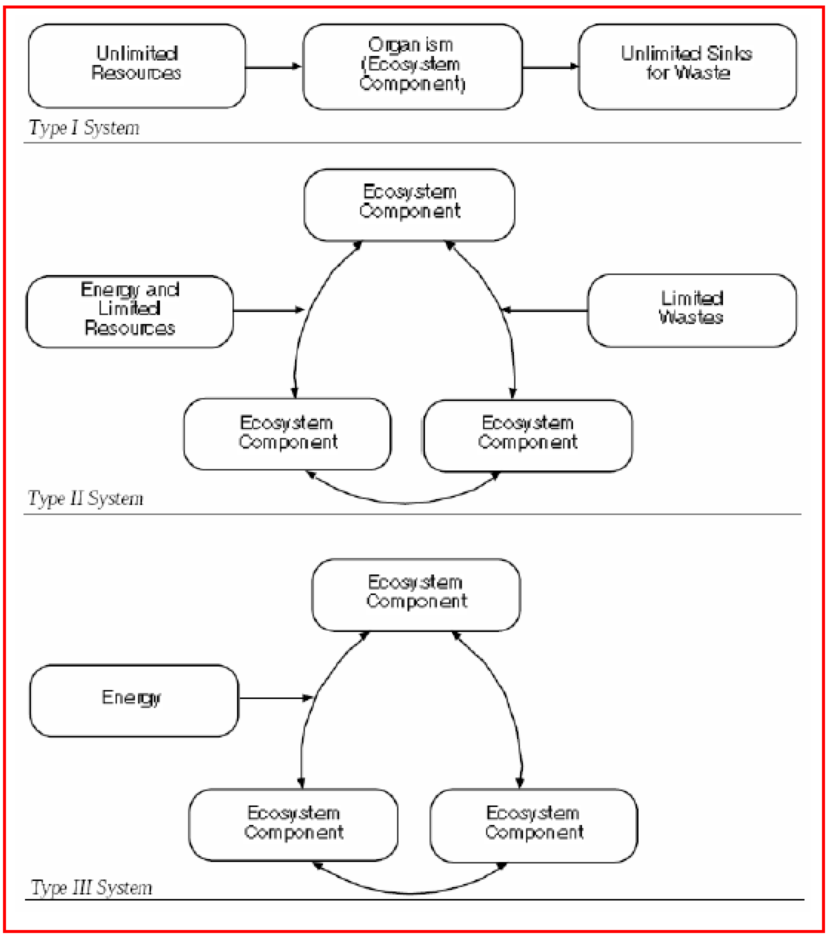
Industrial Ecology (IE) is a framework for understanding the impact industrial systems impose on the environment, and serves to identify and implement strategies for environmental improvement (Garner, 1995 s. 2). Both Tibbs (1992) and Gradel and Allenby (2003), have contributed with definitions on IE, which are getting increasingly accepted as authoritative. Common for both definitions are, that they "*emphasize the interrelationships between natural and industrial systems and the necessity to limit environmental impacts by balancing input, output and ecosystem capacity*" (Basu, et al., 2004 s. 300). However the discussions on how to define Industrial Ecology is numerous, most comprise of the same attributes (Garner, 1995 s. 4). Some of which will be elaborated in the following as they may contribute positively to the analysis on *how to reduce the environmental impacts from music festivals*, through IE, with the Roskilde Festival as the case.

4.1 System approach: Pursue of closed loops

Fundamental to IE is its systematic approach aiming to identify the relationship between anthropogenic activities and environmental impact. It is as such a holistic approach, searching to enclose how the industrial system affects the ecological system (Garner, 1995).

4.1.2 Linear to closed systems

IE pursues closed loop systems. The goal is to go from a linear system, where wastes are dispatched into the environment after consumption, to a closed system where wastes are reused or recycled within the system (Korhonen, 2001). IE find its inspiration in the Ecological System, where a natural dynamic equilibrium has evolved through millions of years of ecological and environmental development, and reached a state where nothing leaves the system, and everything in the system is highly integrated and interconnected with one another. The perfect condition would be, when a company for example could produce a product where the only energy injection would come from the sun, as it considered an infinite energy resource, and nothing leaves the system as waste - an industrial system co-existing in complete harmony with the ecological system (Garner, 1995).



Braden Allenby (1992) exemplifies this in his model on the development from a linear to a closed industrial system.

'Type I Systems'[5] are linear, open systems where the precondition is unlimited input resources, and unlimited possibilities of nature to absorb output wastes. In 'Type II Systems', energy and resources, like wastes, are reduced, and those which are not possible to eliminate completely are reused and recycled to the extent achievable within the system. The existing energy inflow needed consists partially of sustainable energy. 'Type III Systems' follows the closed loop ideal which stems with the Ecological System, elaborated earlier. No waste leaves the system, and the only energy inflow comes from the sun (Allenby, March 1992).

[5] Which is fundamentally the case of the festival now (Corr. with Thomas Niebur)

4.2 The two steps

It has been elaborated how the pursue of closed loops is preferable in IE, and how it is important first to reduce, the energy- and material input and to limit waste output, before addressing systems solutions for environmental improvements. This concedes with the views in Cleaner Production (CP), where a proactive and preventive approach is desirable. CP is as such, an important step in the 'staircase of concepts'[6] towards IE[7] and ultimately fulfilling the ideal of an industrial system, in harmony with the ecological system (Basu, et al., 2004 s. 303). This is what we will address as the first step. The second step will be the system approach, on how to reuse and recycle wastes within the system, and coming up with alternative energy solutions aiming to fulfill the ideal of the closed loop.

4.2.1 Step 1: Energy-, Material- and Waste Reduction

In IE, Material Flow Analysis (MFA's) is one of the most prominent tools for approaching an Industrial System at the macro-level. It helps to understand and quantify the flow of materials and energy in and out of the industrial production or process, to determine the most beneficial areas to work with (Berkel, 2000). In relation to selecting the most appropriate focus, it is furthermore essential that one must understand the dissipation of energy and materials. Garner concludes that "Distinguishing between natural material and energy flows and anthropogenic flows can be useful in identifying the scope of human-induced impacts and changes." (Garner, 1995 s. 10).

4.2.2 Step 2: Closing loops

Jouni Korhonen, describes in an article from 2001, published in 'Journal of Cleaner Production', how Finish CHP[8] plants co-operate with local industries to provide over 80.000 inhabitants with heat and power using local waste materials as fuel. This cooperation furthermore enables the CHP plants to reduce the consumption of external fuels, as coal and

[6] As presented by Hanner in (Basu, et al., 2004)

[7] Rene Van Berkel (2000) sees Industrial Ecology, as a subset of Cleaner Production, when implementing CP on a macro-level. In this paper Cleaner Production is seen as a subset of Industrial Ecology, as we believe the system view in IE, to be the most efficient to reduce anthropogenic environmental impact. This also stems from the perspective, that we thrust a macro perspective is necessary to identify the most beneficial solutions in relation to the reduction of environmental impacts. This concedes with the view presented by Basu and Zyl (2004) and Garner (1995).

[8] Co-production of heat and power.

oil by 40%, facilitating both economic and environmental benefits (Korhonen, 2001). This concedes with the purposes of IE, where Industrial Symbiosis is a fundamental element. The exchange of wastes, energy and other by-products within closely situated firms is called Industrial Symbiosis. Industrial Symbiosis is also referred to as Industrial Ecosystems, and the goal is per se to transform the industrial system so it is suitable to co-exist with the ecological system (Garner, 1995).

4.3 Industrial Ecology at the Roskilde Festival

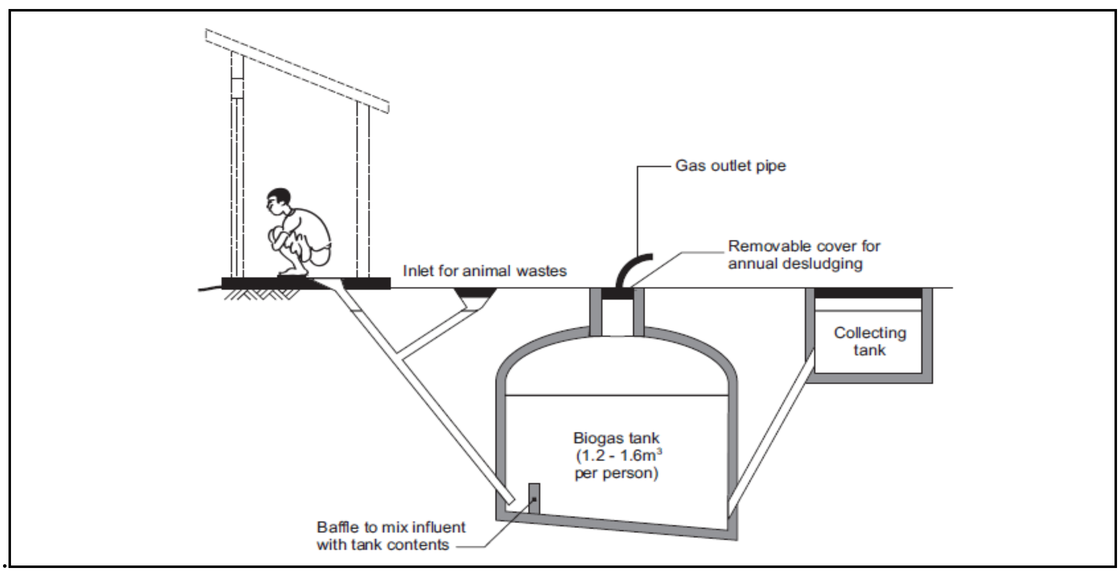
As is has been elaborated above, it is important to find a solution which incorporates the entire system. Industrial Ecology thereby emphasizes that the solution includes all aspects of the festival. In our project this means that we will work with both the waste generation from the guests and the energy production from the diesel generators. We will try to achieve this by looking at the potential of using biogas, as a solution which can in cooperate both aspects.

5. Biogas

As the technology improves in biogas, it is gaining increasing popularity. Many nations are beginning to realize the potential in using wastes to produce energy and meet the growing need for fuels which does not pollute the environment (Tricase, et al., 2008). Biogas seems as such to be the perfect solution to fulfill the aims of *Industrial Ecology*, as it can help us to achieve both our goals; waste minimization and reduction of energy from non-renewable energy, such as fossil fuels.

As will be elaborated later on biogas can be produced from almost anything organic, and transformed into a wide variety of products, for example electricity (Tricase, et al., 2008). In big parts of Asia, especially India and Nepal, the potential in biogas has benefited the countries to improve health, environment, economy and energy conservation (Gautam, et al., 2007). What is especially interesting from these examples is that the gas is produced from a mixture of cattle manure, agricultural residues and *human excreta,* digested in simple local household reactors (Ibid), as the one shown on the picture below, to provide energy for lightning and cooking. This makes us belive, that the festival might be able to benefit from the human execreta as well.

Figure 5: Biogas tank with latherine



Source: (Reed, et al., 2008)

5.1 Anaerobic Digestion

Biogas is a natural gas which is generated from a biological breakdown of organic material such as agricultural waste in the absence of air. The end product consists mainly of methane (CH4) and Carbon Dioxide (CO^2). This product is referred to as biogas (Appels, et al., 2008). It is produced naturally as for instance in the guts of animals and humans when digesting, but it can also be produced artificially in a digestion container. The materials used in this synthetic process can be anything from slurry, to waste water sludge, or even organic household sludge and waste from food industries. The material which is most commonly known for biogas production today is animal manure and agricultural waste (Igoni, et al., 2007).

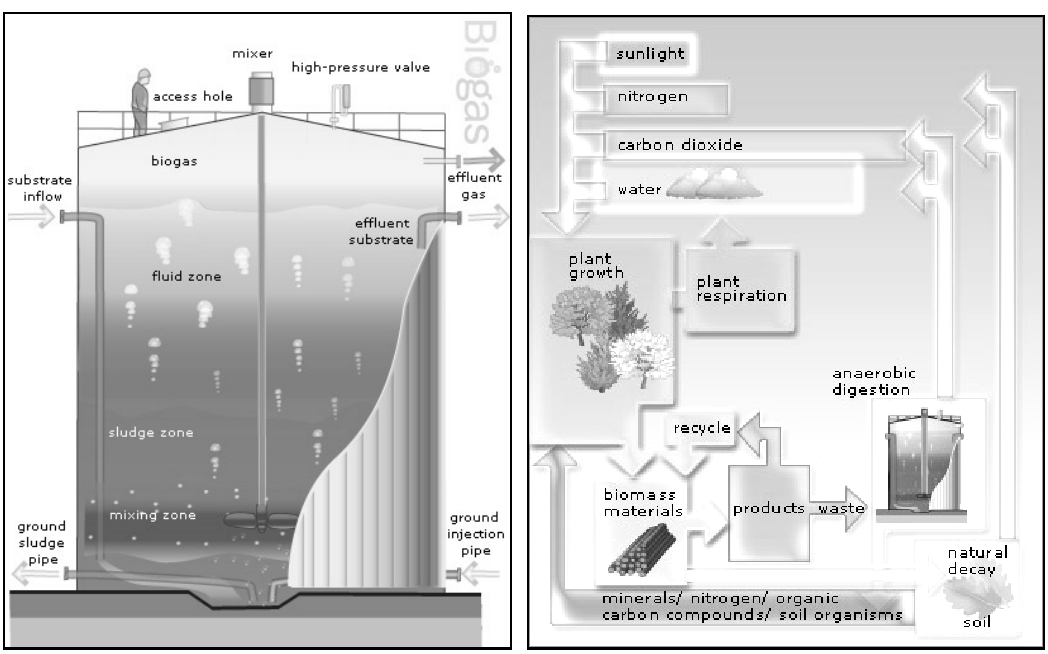
Biogas can be used in a variety of ways, for instance as a substitute for car fuels. However the most common function of biogas is the production of heat and electricity, as it is flammable. Biogas is an environmental friendly energy source, as the CO^2 emissions from the biogas come from organic materials. Emissions are therefore considered neutral.

The process of breaking down biodegradable waste into biogas by microorganisms is called anaerobic digestion. It takes place in an anaerobic digester, a sealed tank where no oxygen can enter the process. A key factor for the biogas process is the material used. Animal manure is not the input with the most potential, as the nutrients and energy content in the manure has already been digested. Furthermore, non degradable ingredients such as plastics or toxic materials can hinder the biological process and need to be removed from the organic waste before injecting it to the biogas plant (Macias-Corral, et al., 2008).

There are some major steps within the digestion which need to be mentioned that lead to the final biogas. In the beginning the organic molecules are converted into sugars and acids, then further on digested into volatile fatty acids (Vfa), which are then deformed into carbon dioxide, hydrogen and acid before reaching the final stage of methanogenisis, where methane, carbon dioxide and water is the end product. Besides gas and water, soil is another byproduct of the process (Macias-Corral, et al., 2008).

In the Mesophilic process the organic waste is mixed in the airtight tank and heated to a temperature of approximately 30-40 degrees. Mesophilic archaeon is a bacteria-like microorganism which lives in extreme environmental situations and contributes to the main digestion procedure in the tank, at this temperature. Where digestion at this relatively low temperature is called mesophilic, thermophilic systems in contrast require a higher temperature of around 50-70 degrees. Thermophilic archaeon is not as stable as mesophilic archaeon, however does the increased temperature achieve a faster digestion process and a higher quality as byproducts are sterilized at this high temperature. This might be relevant in Europe where the legal obligations for the quality of by products such as fertilizers are very strict. The content of for instance heavy metals in fertilizers which are used on agricultural fields are strictly regulated, which will be elaborated later in the chapter.

The residence time of the digestion process varies between 14-40 days depending whether it is a mesophilic or thermophilic digestion. Another relevant factor in the anaerobic digestion concerns the amount of solid and water content in the input material, as it plays a great role in the biogas potential of the material. As mentioned above, the anaerobic digestion does not only produce valuable biogas from agricultural waste, but it also produces useful byproducts such as fertilizers and compost which can be reused on fields as a rich nutrient.



The anaerobic digestion process and how it fits into the eco-system, Source: (REA, 2008)

5.2 The potential of using human manure

As mentioned above, two products are generated through the anaerobic digestion of organic material; soil and biogas. It is therefore essential to look into the biogas and soil potential in the anaerobic digestion of human waste, to determine whether it is possible or not to produce biogas from it. It is furthermore, as written, essential to understand that the potential in the human manure, is dependent on the amount of nutrients for soil and the organic material in the form of volatile solids (solids lost on ignition of the dry solids at 550° Celsius) and dry matter (the amount of material remaining after all the water has been evaporated) for biogas (Backlund, et al., 2003).

5.2.1 Soil potential

To investigate the soil potential we need to see if it is usable as fertilizer and if there are heavy metals or other substances in it, which collide with the national law concerning use of waste in agriculture.

5.2.1.1 Nutrients

As mentioned above is it not only the biogas which constitutes the end products from a biogas plant. Soil is a side product which can be used as a fertilizer on fields due to its rich amounts of nutrient. To investigate the soil potential we will compare the amounts of nutrients in the yearly production of human waste and animal manure.

Table 5.2.1.1: Nutrients in human manure

Substance	Unit	Human Urin	Human Faeces	Pig manure	Cow manure
Mass (MS)	kg/year	365,0	75,0	-	-
Solid (TS)	kg/year	21,9	13,0	-	-
Solid (TS)	%	6,0	17,3	7,0	12,0
Nutrients					
Nitrogen (N)	g/year	4015,0	370,0	-	-
Nitrogen (N)	g/kg MS	11,0	4,9	9,1	7,4
Phosphorus (P)	g/year	365,0	180,0	-	-
Phosphorus (P)	g/kg MS	1,0	2,4	1,8	0,9
Potassium (K)	g/year	913,0	370,0	-	-
Potassium (K)	g/kg MS	2,5	4,9	3,3	6,2

Source: Data found in (Backlund, et al., 2003)

The table shows that 82,95%[9] of MS consists of urin, and 17,05%[10] of MS consists of faeces[11]. This gives us the possibility to estimate the approximate amount of Solids, Nitrogen, Phosphorus and Potassium in the mixture of human faeces and urin.

Solids: $(6 \times 82{,}95\%) + (17{,}3 \times 17{,}05\%) = 7{,}93\%$

Nitrogen: $\left(11 \frac{g}{kg} MS \; x \; 82{,}95\%\right) + \left(4{,}9 \frac{g}{kg} MS \; x \; 17{,}05\%\right) = 9{,}1245 \frac{g}{kg} \mathrm{MS} + 0{,}83545 \frac{g}{kg} \mathrm{MS} \approx 9{,}96 \frac{g}{kg} \mathrm{MS}$

Phosphorus: $\left(1 \frac{g}{kg} MS \; x \; 82{,}95\%\right) + \left(2{,}4 \frac{g}{kg} MS \; x \; 17{,}05\%\right) = 0{,}8295 \frac{g}{kg} MS + 0{,}4092 \frac{g}{kg} MS \approx 1{,}24 \frac{g}{kg} MS$

Potassium: $(2{,}5 \frac{g}{kg} MS \; x \; 82{,}95\%) + \left(4{,}9 \frac{g}{kg} MS \; x \; 17{,}05\%\right) = 2{,}073 \frac{g}{kg} MS + 0{,}83545 \frac{g}{kg} MS \approx 2{,}91 \frac{g}{kg} MS$

The calculations above show us that the percentage of solids in the human waste lies between the percentages of soil in cow and pig manure. The K values also lie in between. Even though the nitrogen lies a little above, and the phosphorus a little below the values in the animal manure, the differences are not severe. This gives us the reason to believe that the soil generated from human manure, as a byproduct in the generation of biogas, is as well as the soil generated from animal manure, usable.

5.2.1.2 Legal Obligations

Though it seems possible to use the fertilizer from the human waste, the fertilizer needs to pass the legal restrictions in regards to heavy metals and other substances which would otherwise harm the environment. Here the legal possibilities will be tested to find out the quality of the soil which is generated when providing a biogas plant with human manure and organic waste from the festival.

If the manure contains a high number of heavy metals, the possibility to use the resulting soil might be limited. A toxic byproduct could even be a threat for the environment as it would have to be disposed in another way if it cannot be used for agricultural purposes. The table below provides an overview:

[9] (100/(395+75))*365
[10] (100/(395+75))*75
[11] It is very likely that the percentage of urin in the wastes is even higher, as it is presumed that people consume much more liquid due to the festival and the beers consumed.

Table 5.2.1.2: Environmental regulation

Substance	Unit	Env. regulations	Human Urin	Human Feaces
Cadmium	mg/kg TS	0,8	0,02	0,2
Mercury	mg/kg TS	0,8	0,02	0,4
Lead	mg/kg TS	120	0,03	0,4
Nickel	mg/kg TS	30	0,1	1,5
Chromium	mg/kg TS	100	0,2	0,4
Zinc	mg/kg TS	4000	0,7	219
Copper	mg/kg TS	1000	1,7	22,3

Source: Generated from data found in 'Bekendtgørelse nr. 49 af 20. januar 2000 om brug af affaldsprodukter til landbrug og beslægtede formål ('Slambekendtgørelsen')' [12].

The table shows that all heavy metal substances in human urine and human feaces are far below the legal restrictions and do thereby not impose a threat on the environment when used for agricultural purposes. This signifies that the soil, which is produced as a byproduct in the biogas plant, does not collide with the environmental regulations in terms of heavy metals. Therefore the soil generated through the anaerobic digestion of human manure can be reused as fertilizer. Furthermore there is no legal restriction saying that manure from humans cannot be used as a fertilizer for agricultural purposes (Backlund, 2002).

5.2.1.3 Other considerations

Even though it is possible regarding both nutrient and legal matters, there are some ethical considerations which might influence on the potential regarding the soil as well. The biogas plant in Hashoej[13] has therefore been questioned regarding the soil, and the problem was not the manure as such, but as described the soil is made into fertilizer used in farming. Some of the farmers have legal obligations to Danisco, which means that they cannot use fertilizer made from human waste (Corr. with John Hansen). The same is the case in many other biogas plants in Denmark (Backlund, et al., 2003). Nonetheless experiments have been carried out with success out on a Museum in Møn where human urine was used by local farmers as a fertilizer without problems (Backlund, 2002).

[12] Declaration nr. 49 of the 20th January 2000 concerning the use of waste in agriculture and alike (our translation).
[13] The biogasplant in the closest proximity to the festival (34km).

5.2.2 Biogas potential at the festival

As described above, the biogas potential depends on the amount of dry material (TS) and volatile solids (VS) in the waste material. In this case the amount of TS and VS in the human waste. TS should be about 2-4% of the waste, and the percentage of VS should be about 80% of TS for the optimal digestion process (Backlund, et al., 2003; p.61)

Arne Backlund and Annette Holtze (2003) use the following standard values for human waste:

- 200g faeces, consisting of 35g dry material (TS) and 32g volatile solids (VS)
- 1,5l urin, consisting of 60g dry material (TS) and 45g volatile solids (VS).

If we combine these numbers with table 3.1.1.1, and the waste flow sheet presented in the next chapter, we will be able to give an estimate on the approximate total amount of TS and VS in the human waste on the festival.

First of all these numbers give us the opportunity to estimate the concentration of respectively VS and TS in the human waste, presented in the following table (table 5.2.2.).

Table 5.2.2 : Mass percentage of VS and TS in human waste

	Faeces	Urin
TS	$Mass\%\,TS\ of\ faeces = \frac{35g\ TS}{200g}\ x\ 100\% = 17{,}5\%$	$Mass\%\ TS\ of\ urin = \frac{60g\ TS}{1500g}\ x\ 100\% = 4\%$
VS	$Mass\%\ VS\ of\ faeces = \frac{32g\ VS}{200\ g}\ x\ 100\% = 16\%$	$Mass\%\ VS\ of\ urin = \frac{45g\ VS}{1500g}\ x\ 100\% = 3\%$

Secondly our investigation has showed us, that the Roskilde Festival generates 5380 ton of human manure. Calculations earlier has shown that 82,95% of the total mass pr. year consists of urin, and 17,05% of the total mass pr. year consists of faeces[14]. This means that, if we presume that the proportions are the same, the generation of dry material and volatile solids on the festival is:

[14] See table 5.2.1.1

$$TS\ Generated: TS\ in\ faeces\ (5830000kg * 17{,}05\% * 17{,}5\%) + TS\ in\ urin\ (5830000kg * 82{,}95\% * 16\%)$$
$$= 367392\ kg\ TS$$
$$VS\ Generated: VS\ in\ faeces (5830000 * 17{,}05\% * 16\%) + VS\ in\ urin\ (5830000 * 82{,}95\% * 3\%)$$
$$= 304122\ kg\ VS$$

Thirdly this gives us the tools to estimate the biogas potential in the human manure on the Roskilde Festival. As it has been impossible for us to find data on the biogas potential of the volatile solids in human manure we're using the values from the generation of VS from primary sludge[15] which is 0,33m3 pr. kg VS (Backlund, et al., 2003 s. 83). This gives us a biogas potential of $\frac{0{,}33\ m^3}{kg}\ x\ 304122\ kg = 101.374 m^3$ in human waste.

The biogas potential in one cubic meter of Biogas is about 6 kWh calorific energy[16]. However the production of energy in a biogas powered electrical generator, found in CHP plants normally equals about 2kWh pr. m^3 as the rest of the energy is turned into heat in the process[17] (Electrigaz, 2008). This means that the energy potential in the human waste equals about $2x101.374 = 202748kWh$ of usable electricity.

However, as described in the beginning of this chapter, the optimal ratio of TS is about 2-4%, and that 80% of this is VS. But as it is shown in the above table this isn't exactly the case of the human execreta, which means that if the ratio would be optimal, the production of biogas would be much higher. Examples from mixing animal manure and muncipal solid wastes, have showed that the co-digestion can result in an increase of in the biogas potential of up to 300% (Macias-Corral, et al., 2008) which is also why it is feasible to look at the possibilities to include other wastes from the festival.

[15] Sludge accumulated at the bottom of the primary sedimentation basin.
[16] Heat producing energy
[17] If the biogas would be turned into energy outside a CHP-plant the energy from the heat would be wasted, which is also why, the most efficient way of burning the biogas would be in a CHP-plant.

5.3 The biogas potential in waste

To give the reader a overview of the wastes generated on the festival, the following table has been generated from the data in Appendix 1.

Table 5.3: Waste flows

Waste flows				
Articles	**Amount**	**Total Weight (in KG)**	**Material**	**Type of waste**
_Beer cups	804000	40200	Plastic	Non degradable
_Soda cups	304000	15200	Plastic	Non degradable
_coffe cups	308000	15400	Paper	Degradable
_Plates	318000	44520	Paper	Degradable
_Knife and forks	536000	16080	Maize Starch	Degradable
_Napkins	851000	1702	Paper	Degradable
_Pockets or bugers	391000	782	Paper	Degradable
_Packaging*	unknown	unknown	unknown	unknown
_others**	unknown	unknown	unknown	unknown
Total weight		131400		
Others				
_Toilet manure (in ton)***	5380		faeces+urin+toiletpaper	Degradable
_water (in liters)	10000000			

* We have not included this in the assingment

** This include articles guests buy outside the festival area, and dispose on the festival.

*** Toilet paper is included but not accounted for in the following

Source: See appendix 1, and own calculations

5.3.1 Tableware, napkins and cups

Tableware, napkins and cups can be reused in forms if input into the biogas production. The festival has made a great effort in the past years to substitute plastic by other degradable material. plates and coffee cups is now made of paper instead of plastic, and tableware made of organic maize starch is handed out. Therefore most of the material used at the festival is already organic, which means that it can be digested by biological microorganisms. The only problem with tableware is the plastic cups used for beer and soda, which will be analyzed in the following section.

5.3.2 Plastic cups

However when looking at the flow analysis, the 804,000 beer cups and 304,000 soda cups are made of plastic and thereby constitute a big environmental problem. Plastic cups cannot be reused as energy input as burning the plastic is toxic. The cups can therefore not be used in the biogas plant, as it would hinder the digestion process and produce toxic by products. As plastic cups constitute the majority of the garbage form the food stands, another way of dealing with this waste needs to be found, as it cannot just be left out. A feasible substitution for using plastic cups is needed which can reduce the large amount of non organic waste currently present.

5.3.3 Substituting plastic cups

These alternatives can include all kinds of material which are organic and which therefore could be included into the biogas digestion process together with the manure, tableware, paper plates and paper cups. One option could be to use ecological corn cups with are 100% compostable cold cups (ECO Products, 2008). These cups look like normal plastic cups, however unlike petroleum based cups are theses cups made of corn, which is a renewable material. When comparing prices it becomes evident that substituting the existing cups with ecological cups would not have a major impact on the costs. A regular 0,5 liter plastic cup used for the beers costs in average 0 ,80 dkkr (Corr. Niels Van Binjin). One 0,5 liter corn cup would in comparison costs around 0,7 dkkr[18]

Maybe when ordering such a large amount as would be needed for the festival area, the cost would even be lower. It is also possible to print logos on the plastic cups, where the Management could have the possibility to visually demonstrate to their guests about their initiative of reducing plastic waste. This would comply with both the management’s mission to promote the festival as environmental friendly, and it would not collide with the festival’s budget, while at the same time enabling the guests a fast and uncomplicated waste disposal, meaning that they would not have to return their beer cups to the drinking stalls but can just through them out into the purposed garbage can. The corn cups presented above can be seen as an example for degradable alternatives that could substitute the plastic which has been used for the past years. Using such kind of biological cups instead of plastic cups would increase the amount of input for the biogas production and it would at the same time reduce the amount of non organic waste, which will bring a major improvement to the environmental situation.

[18] 10000 cups of 16 oz cost $126,95 = 726 danish kroner= 726/1000= 0,726 danish kroner for each cup (ECO Products, 2008)

Cup made of 100% biodegradable material. Source (ECO Products, 2008).

5.3.4 Waste disposal system

An important requirement which needs to be highlighted is that the waste sorting plays a major role when collecting the waste materials at the festival area. It is essential that no plastic or other toxic waste is mixed with the above mentioned organic waste. Therefore a garbage sorting system needs to be developed which is easy and quickly understandable for all guests, so that even the ones with a high percentage of alcohol in their blood are able to see at fist sight in which garbage can to dispose their cups, and in which ones their plastic waste. As mentioned above is the majority of the food articles and tableware sold in the festival area already made of organic material, however might the guests themselves have waste which is non organic such as cigarette packages or broken lighters which they need to be able to dispose without disturbing the purity of the degradable waste.

The group suggests a two garbage can system to keep it simple, where one garbage (it could be green, and painted with an understandable figure) is for the all above mentioned table ware, paper waste and the organic cups, while the other one would be for everything which is not organic.

In order to secure the collection of usable Input for the biogas production, the biodegradable waste materials needs to be separated from waste which is not degradable. This also includes the manure collected. In relation to the toilets, the sorting could be a little more difficult, but instructions within the toilets could be an effort to hinder non degradable materials to enter the system.

5.4 Summary

Even though it is not possible for us to look into the biogas potential of the mixture of human execrate and the other wastes, it has been made evident that there is an enormous biogas potential to reuse waste generated on the festival to in a biogas plant, especially as all the waste is, or can easily be turned into biodegradable waste. Furthermore the Biogas plant in Audebo will most likely be interested in buying the organic mass for the production of biogas as long as it sorted probably (Corr. John Hansen).

It is furthermore clear that the biogas cannot be directly used as a substitute for the diesel generators, as it would be necessary to transport the biodegradable material to a CHP-plant in the proximity of the festival to generate the gas. Here it would furthermore take about 14-40 days to generate the gas through the anaerobic digestion process (Backlund, et al., 2003). Therefore other measures must still be taken to substitute the diesel generators.

Nonetheless, the wastes will no longer be dispatched into the nature, after being treated at purification plants or alike. Furthermore it will be a contribution to the national energy mix from renewable energies[19]. This will benefit both the environment due to the reduction in the percentages of fossil fuels used to produce energy to the grid. Furthermore it will benefit the Roskilde festivals economy, as there obviously is no apparent expenditure in the production of the organic material. The waste material needs to be collected and transported away already and the fact that they would probably be able to sell the mixture to a CHP plant.

[19] In Denmark 28,5 percent of the energy in the grid comes from renewable energy, especially wind (Energinet.dk, 2008).

6. Biodiesel

In order to test if biodiesel is a feasible solution to substitute petro diesel, three main criteria will be analyzed: Environmental target, technical limitations and economic possibilities. In the end, the energy potential of biodiesel for the Roskilde Festival will be concluded. First an overview of what biodiesel is and how it is produced will be provided.

6.1 Introduction

Biodiesel is a renewable energy source getting more and more attractive with diminishing fossil fuels available and environmental awareness growing rapidly. Just like in biogas, the material used for the production of biodiesel comes from organic sources. The input material includes a variety of vegetable oils, nut oils and inedible oils demonstrated in the table below. The most common oils used are rapeseed oils, soybean oil, coconut oil and sunflower oil.

Table 6.1: Oil species for biodiesel production

Group	Source of oil
Major oils:	Coconut (copra), corn (maize), cottonseed, canola (a variety of rapeseed), olive, peanut (groundnut), safflower, sesame, soybean, and sunflower
Nut oils	Almond, cashew, hazelnut, macadamia, pecan, pistachio and walnut
Other edible oils	Amaranth, apricot, argan, artichoke, avocado, babassu, bay laurel, beech nut, ben, Borneo tallow nut, carob pod (algaroba), cohune, coriander seed, false flax, grape seed, hemp, kapok seed, lallemantia, lemon seed, macauba fruit (*Acrocomia sclerocarpa*), meadowfoam seed, mustard, okra seed (hibiscus seed), perilla seed, pequi, (*Caryocar brasiliensis* seed), pine nut, poppy seed, prune kernel, quinoa, ramtil (*Guizotia abyssinica* seed or Niger pea), rice bran, tallow, tea (camellia), thistle (*Silybum marianum* seed), and wheat germ
Inedible oils	Algae, babassu tree, copaiba, honge, jatropha or ratanjyote, jojoba, karanja or honge, mahua, milk bush, nagchampa, neem, petroleum nut, rubber seed tree, silk cotton tree, and tall.
Other oils	Castor, radish, and tung

Source: Demirbas 2008

Biodiesel is generated through a chemical process, called transesterification, where the oil molecules[20] are combined with alcohol, usually methanol or ethanol. In order to speed up the reaction process, a catalyst, usually sodium hydroxide is added (Demirbas 2008). The mixture is heated to approximately 50°C in a procedure that takes between 4-8 hours. The products resulting from the procedure is glycerin and biodiesel. The side product from biodiesel production is glycerin, which can be purified afterwards and reused for instance as industrial degreaser or soap (Demirbas, 2008).

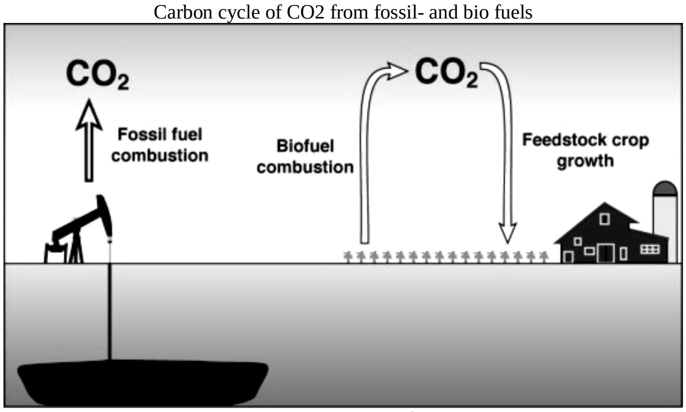
[20] Animal and plant oils usually consists of triglycerdine, free fatty acids together with glycerol

6.2 Environmental targets

Biodiesel is derived from organic sources, and shares most of the same properties as biogas: it is renewable, biodegradable, non toxic and is thereby a positive contribution for the future energy supply. Another advantage in biodiesel is that it, unlike petro diesel, does not contain sulfur.

Plants are grown through the photosynthesis process generated by the sunlight and the CO^2 in the air. Biodiesel comes from plants which already absorbed the CO^2 from the air and therefore no extra CO^2 is released to the ecological system when the biodiesel is burned. Thereby it is regarded CO^2 neutral. This is why biodiesel does not impose an environmental threat, like normal diesel does and substituting the diesel with biodiesel on the festival will remove the CO^2 emissions and meet the first environmental target.

Carbon cycle of CO2 from fossil- and bio fuels



Source: www.communityfuels.com

Furthermore biodiesel releases no visible smoke and odor (Demirbas, 2008), which is a major advantage not merely for the environment but also for the health of the festival guests and volunteers.

Waste reduction is another environmental target in this report. Biodiesel is mainly produced from vegetable oil, however waste cooking oils can also be a cheap input into the biodiesel production (Demirbas, 2008, s. 16). This could be a possibility for the festival; however the amount of cooking oil used at the festival is not significant. Other organic waste can so far not be reused as input to the biodiesel process. Despite the advantage of being CO^2 neutral, the biodiesel proposal does not deal with the majority of the waste materials generated at the festival and does therefore not contribute to achieve the second of the environmental targets set up regarding waste reduction.

6.3 Technical limitations

Biodiesel and diesel share similar chemical characteristics which is why biodiesel easily can be used in any regular diesel generator without major modifications. Furthermore biodiesel is more lubricating than normal diesel, which has the positive side effect that the machine is greased better and lengthens the lifetime of the engine. A technical disadvantage is the lower energy content of biodiesel, which means that more biodiesel is needed to achieve the same amount of diesel energy (Demirbas 2008).

All in all it is technically possible to use biodiesel in the generators currently used on the festival.

6.4 Economic possibilities

The last aspect which will be examined is the economic aspect of using biodiesel. Biodiesel is due to the high production costs of vegetable oils and increasing food prices 1½ - 3 times more expensive than petro diesel, depending on the feedstock and the geographical area where it is produced (Demirbas 2008). Higher prices in comparison to diesel, is therefore one of the disadvantages of biodiesel. Another major disadvantage of biodiesel is that using vegetable oils puts a big pressure on the food market, which creates a risk especially for developing countries, as the prices on basic foods are rising (Srinivasan, 2008). However many of the disadvantages can be solved by using inedible oils as input, such as rubber tree and cotton oils instead of rapeseeds and other food products (figure 6.1). Furthermore it is possible that the price on biodiesel will decrease in the future as it gets more commonly used and as it gets increasingly popular.

6.5 The energy potential in biodiesel for the festival

The energy potential (HHV[21]) in diesel, according to Demirbas (2008), is approximately 43mJ pr. kg[22], and we know the festival uses 21343 l of diesel (corr. Thomas Niebur). The amount of energy used on the agoras thereby sums up to:

$$21324L\ diesel \approx 21324kg\ \text{diesel} \rightarrow 21324kg\ x\ 43mJ\ = 916932mJ\ ^{23}.$$

As the HHV value of biodiesel is only 39-41 mJ/kg (Ibid)[23] and thereby lower than the one of diesel, we need more biogas to produce the same amount of energy for the festival:

$$\frac{916932mJ}{40mJ/kg} = 22921{,}3l$$

6.6 Summary

The benefits of biodiesel being renewable, biodegradable and non toxic pledge a positive alternative to the diesel, looking at it from an environmental perspective. Yet biodiesel does not solve the problem of waste generation, even though in the future the technology might be developed to reuse other waste products apart from waste cooking oils. Biodiesel does not require any major adjustments or technical changes in order to be used in a diesel generator, as they both share similar characteristics. Biodiesel is a better lubricant and can lengthen the lifetime of the generators. Furthermore; the energy content in biodiesel is lesser than in petro diesel, which is why the generator will require more liters, is it feed with biodiesel. In order to achieve the same amount of energy, the calculations have shown that the festival needs approximately 1600 liters more biodiesel, which will results in an economic drawback, as biodiesel is 1,5-3 times more expensive than diesel.

[21] HHV = Higher heating values, is the amount of heat released by a specified quantity (initially at 25 °C) once it is combusted and the products have returned to a temperature of 25 °C.
[22] 1kWh equals approximately 3,6 MJ
[23] As the HHV varies we have chosen 40, as it the average.

7. Alternative energy systems

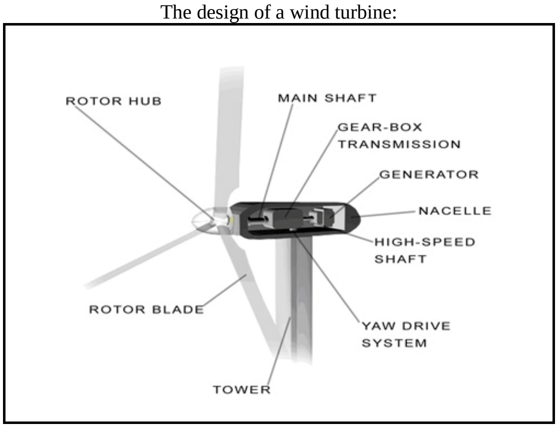
In this investigation we have chosen to look into the possibilities of solar- and wind energy apart from biodiesel, as both are considered clean energy[24]. This is why these alternative energy systems are going to be compared to biogas in the following chapter. In order to substitute the diesel generators on the Roskilde music festival, the solar or wind alternatives need to be able to substitute the 15 generators which are each able to produce 60 to 80 kW (Thomas Niebur) – meaning that we need to substitute an effect of 15x80kW → 1200kW.

7.1 Wind energy

Wind energy has developed rapidly since the middle of 1970s and wind power now addresses 'one of the fastest growing methods of electricity production' (Fenger 2007) and is one of the biggest contributors to the renewable energy in the grid. In Denmark for example, 18,5 percent of the grid energy comes from wind (Energinet, 2008). Nowadays, wind has developed into a modern energy industry. The biggest advantage of wind energy is, that it produces no solid-, liquid- or gaseous waste (Gipe 1995).

Nowadays, almost all commercial wind turbines are horizontal axis machines with rotors using two or three airfoil blades (Pecen, 2000). The picture below illustrates that a wind turbine contains three parts: blades, nacelle and tower.

The design of a wind turbine:



Source: http://wings.buffalo.edu

[24] No CO2 emissions

Even though wind energy is considered clean energy, there is still a range of downsides to the technology. Wind occurs because of variations in temperature and pressure in the troposphere. Wind is thereby influenced by the global climate. Furthermore the character of the wind is dependent on local elements such as variations in the landscape, local vegetation and other obstacles. The wind is captured by the wind turbine blades, and then transformed into electricity through a mechanical (kinetic) process. In detail this happens when the mechanical energy turns the shaft around a gearbox which forms electrical power. The power in the wind is $P=1/2*A*\rho*V^3$ [Watt/M^2] (Pecen 2000). P is the power which be produced, ρ is the air density, A is the area of the blades and V represents the direction of the wind through the rotor hub. The 4 elements mentioned thereby determine the factors which influences the energy that the windmill is able to produce. This function points out two important factors which can be influenced: the undisturbed wind and the size of rotor blade. One drawback in relying on wind energy is that the system is weather dependent, meaning that the energy potential is always in relation to the amount of wind present in the air.

Another downside is that wind energy is in the short term very expensive, because of the high establishment price[25]. Tricase, et. al,. (2008) estimates that the establishment cost of a 20mW wind energy system will be at least be € 21,812,800. This number is of cause depending on the different companies, different models, type of ground etc., but it gives us a good idea of how cost intensive wind energy actually is. Another possibility is to buy small windmills, to exchange only part of the energy from the generators. A possibility could be 'The Air Dolphin' (see appendix 3), which is a smaller and cheaper solution, but only being able to produce 1kW, is no alternative for the generators.

The negative environment impacts of windmills are electromagnetic interference, noise and visual impact which has consequences for animals and the people living in the area.

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[25] Establishment costs include: cost of wind turbines, civil works, electrical infrastructure and grid connection, installation costs, project management, insurance, legal costs etc.

7.1.2 The potential of using wind energy on the festival

It will be a major financial disadvantage in regard to the festival management's possibilities to use wind energy and making such a long term investment. As elaborated on earlier in the project, the Roskilde Festival management gives a large amount of their profits to charity organizations which means that their ability to invest into expensive equipment is limited. Furthermore it is worth mentioning the short usage time of only days, which expands the period of time before the investment will pay off.

In the example above it was illustrated that 20mW costs about 21million euro in establishment costs. It can be drawn form this that each mega Watt system cost over 1 million euro. Therefore a solution which can produce 1200kW (1,2mW), which is needed to substitute the generators, is an enormous expense. Beside the economic difficulties, noise pollution reduces the potential of using wind energy at the festival as well.

7.2 Solar energy

Solar energy is the largest resource among all the renewable energies as it is inexhaustible, and the immense sunlight could easily cover the global energy demand, making other energy sources unnecessary, if it was technologically possible (Williams, 2005; p. 309). In contrast to wind energy, solar energy can be formed directly into solar thermal energy or electricity (Geuder, et al., 2006; p.44). Naturally the larger the surface of the solar construction, the more energy can be absorbed from the sun.

The energy from the sun can be transformed into energy in two different ways; through the solar thermal- or the photovoltaic (PV) approach. Solar thermal, uses the energy from the sun and transforms it directly into warm water or space heating in buildings. Heating water is as such the most popular reason for private users to install solar thermal devices (Quaschning 2006; p77). This is however not the use of solar energy, which is relevant to this project. The Photovoltaic process transforms the sunrays into electricity through solar cells. The solar energy is absorbed in the solar cells and transformed into energy. The amount of energy generated through from the PV process is, however, dependent on the weather conditions, as the PV cells uses the light, and not the heat from the sun, the energy generated in cloudy weather is limited, and no energy can be generated during night time. Therefore a solar power system normally includes a storage system so the energy can be collected and stored for use in bad weather conditions. The energy can furthermore be fed to the grid, when the batteries are full (Leipoldt, 2008).

Compared with other renewable energy sources, solar energy makes no noise, has a low visual impact and no gaseous emissions. The problem however is that 'it is 5 to 10 times as expensive as conventional power generation' (Grubb, 1997; p. 103). An example of the kW price is given in table 7.2a below.

Table 7.2a: Cost pr. Watt

Watts	cost pr. watt (dollars)	Total System Cost (dollars)
100	9	900
2000	6-10	13,000-20,000
5000	6-8	30,000-40,000

Source: William J. Keese (2003)

Furthermore solar energy is quite space-intensive, as shown in table 7.2b below. The higher the efficiency of the system, the higher is the price (Keese 2003).

Table 7.2b: Roof area pr. Watt

PV module efficiency (percent)	PV capacity rating (watts)							
	100	250	500	1000	2000	4000	10000	100000
	Roof area needed (m2)							
4	3	7	14	28	56	111	279	2787
8	1	4	7	14	28	56	139	1394
12	1	2	5	9	19	37	93	929
16	1	2	4	7	15	30	74	743

Source: William J. Keese (2003)

7.2.1 The potential of using solar energy

Even though the energy generated by the solar panels can be collected and stored for use in bad weather conditions or feed to the grid, when the batteries are full, solar energy is unstable. The total amount of sunrays, which refract on the surface of the solar panels, are dependent on location, weather conditions, the seasons of the year and the time of the day. In the worst case, it could be cloudy during the one week of the festival, which means that the energy generation from the

Photovoltaic process will be diminished, and might not produce enough energy alone to substitute the diesel generators.

The current diesel generators can produce 80kW of energy, which means that the substitution of one generator would take up: $743x80\%\ to\ 2787x80\%\ m^2 \rightarrow 594{,}4m^2\ to\ 2230m^2$ depending on the efficiency[26] of the PV module (see table. 7.2b)[27]. This is a relatively big amount of space for one solar generator, taking into consideration that the entire festival takes up 438.222 m^2 (Appendix 1) and the substitution of the 15 generators with solar energy seems completely out of proportions.

Furthermore the kW price of solar energy is also a limitation in regard to the potential of using solar technology. As is shown in Table 7.2a the kW price falls the bigger the system is. Even 5kW would cost 30,000 to 40,000 dollars alone, making the substitution of just one generator (60-80kw) an enormous expense.

It is possible to rent the solar devices, lowering the price pr. kW but it would not solve the problem of the devices being very space-intensive. Some examples of rentable solar generators are given in Appendix 2.

7.3 Summary

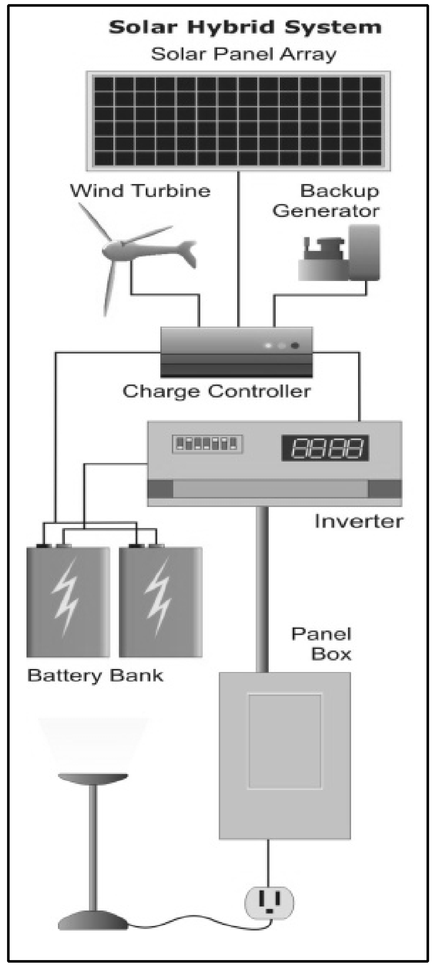
As analyzed above, is a single supplement in forms of either wind or solar systems not the most reliant way to ensure enough energy supply, as both systems are weather dependent. Furthermore is the option of buying a large windmill which could supply the agoras with sufficient energy, outside the economic reach of the festival management. The same can be said about buying a large scale solar energy system. Solar panels furthermore have the disadvantage of requiring big areas which might not be available to such a large extend. In the analysis it was stated that solar energy has the advantage of having low visual impact as it can be set up on top of a roof. In the case of the festival however, there are not many buildings available to set up such a large scale system. It would have to partly be placed on the grounds, and the visual impacts for the guests would be severe.

[26] Percent of sunlight converted to electricity

[27] The table provides the information on how much roof area a 100.000 watt (100kW) occupies, this is why these numbers are multiplied with 80% to get an approximate number of square meters needed to substitute one generator of 80kW.

Furthermore, a solar system needs either a big battery or backup generator for night uses or in case the weather conditions are not ideal. Both solar and wind energy share the same disadvantage: high price and limitation due to uncertain weather conditions.

7.3.1 Hybrid wind-solar system



In order to obtain maximum use and ensure reliability, the most effective solution would be to combine wind and solar energy.

To be more effective, a solar-wind hybrid system as shown in the figure to the right is a good option. This system is more reliable and small scale systems do not need a big amount of investment in itself. A hybrid system consists of a wind turbine, a solar panel and can also be equipped with a backup generator. Both systems can work at the same time and promote efficiency. The cost effectiveness[28] and space effectiveness[29] will be more or less the same .which is why the problems of a high investment prices will be the same. Hybrid systems can solve the problem of reliability and effectiveness, however it cannot be described as being feasible regarding the economic possibilities of the festival.

[28] Cost per kilowatt
[29] Square meter needed per kilowatt

8. Feasibility analysis and solution proposal

In this section all three solution proposals will be compared to the proposal of using Biogas, and in the end it will be determined which meets the LCD framework best. Industrial Ecology will be used to determine which proposal will bring the festival closer to the ideal of a closed system. The analysis will therefore demonstrate the most feasible solution.

We have defined two main objectives on which to evaluate the proposals: Environmental targets and the LCD Framework made in relation to the Roskilde Festival's Management.

Criteria	Wind	Solar	Biogas	Biodiesel
Environmental targets (Industrial Ecology)				
Reduction of CO2 Emissions (from diesel generators)	++	++	- -	0
Reduction of waste	- -	- -	++	0
LCD Framework				
Green image	++	++	0	0
Resources (Economic possibilities and competiveness)				
- *Short term*	- -	- -	++	-
- *Long term*	++	++	++	0
Performance				
- *Reliability of energy supply*	+	- -	- -	++
- *Consumer demand and consumer needs*	+	-	- -	++

8.1 Environmental targets

In the chapter on industrial ecology, two goals were defined, which we aim to pursue to improve the environmental situation on the festival; reduction of waste from the guests and CO2 emissions generated by the diesel generators. The aim is to find a solution which can in cooperate both of the problems.

8.1.1 Reduction of GHG emissions

Our analysis shows, that biogas can produce enough energy needed in the agoras to substitute the diesel generators; however, the energy cannot directly be used on the festival. Wind, solar, and biodiesel presented in the analysis chapters all have in common that CO^2 emissions are either neutralized or eliminated. While it is possible to use wind or solar energy to fully substitute the diesel generators and eliminate all CO^2 emissions, biodiesel can merely substitute the diesel with a more environmentally friendly alternative, which neutralizes the emissions.

8.1.2 Reduction of waste

The second environmental goal in relation to Industrial Ecology is the reduction of waste at the festival. Biogas is the only solution which incorporates the waste and reuses it into the biogas plant, meaning that waste will be minimized to a large extend. If the plastic cups, which currently contribute to a big percentage of the waste, are substituted with biodegradable cups as suggested the only non degradable wastes on the stage areas are the one the guest bring themselves. This is both a positive contribution for the environment, and makes it easier to keep degradable and non-degradable wastes apart.

Solar and wind energy system suggestions do not deal with the waste and biodiesel does not reduce the waste as such, but there is, as described in the analysis, a potential in using waste cooking oil to produce biodiesel as well. Even though it is possible, the rest of the waste materials will still not be dealt with.

8.2 LCD Framework

8.2.1 Green image

Looking at the management criteria, which were presented in the framework, the green image is an important aspect as well. As the biogas will be produced outside the festival area the process are not visible the guests. The effort of the Festival operators are therefore not as obvious and easy recognized as they would like to, in order to promote themselves as a being a green festival. The same is the case for the biodiesel. Wind, solar and hybrid systems have an advantage compared to the biogas proposal, as the environmental effort done by the festival operators is directly visible to the guests. This is also a big chance to influence on the audience and make them aware of the possibilities of renewable energies. However other measures could be taken to promote the biogas or biodiesel as an environmental effort, as for instance the corn cups, suggested for beers and sodas, could be printed with a logo or a phrase which highlights and emphasizes the reuse of the waste for biogas production.

Furthermore, achieving a green image might even be an important factor in relation to the festivals competiveness discussed later in this chapter.

8.2.2 Resources

The resources available constitute an important factor when implementing new energy technologies. Producing Biogas does not mean an extra expense for the festival, as the input waste materials is free and transportations costs is expected to be similar. It is furthermore possible that the festival can sell the biomass to a CHP plant freeing economic resources to use elsewhere. However, the correspondent from Hashöj biogasplant has stated that it is not be possible to use the human manure into a CHP plant, as companies will not be willing to buy food from agricultural fields where the soil from human manure has been used as fertilizer. The rest of the organic waste materials can however be used without problems.

The biodiesel proposal does not require any form of investment, as the same diesel generators which are normally rented, can be used. The cost of biodiesel is currently 1,5 - 3 times as expensive as diesel, and furthermore the HHV value is below the one of diesel implying that they would need to buy more fuel, which is why biodiesel will demand more of the festivals resources.. In the long term, there is even a chance that biodiesel might get cheaper, making it more feasible.

Investment into merely wind energy is a huge expense which, in the short term, lays outside the economic framework the festival. The long term perspective can be more feasible, if the festival can sell the wind energy the rest of the year when the festival is not taking place. Building a windmill would furthermore imply that the festival owns the festival ground, which is not the case. A windmill could therefore not be placed on the festival ground unless they choose to buy it as well. Mobile solar generators can be a more feasible solution when it comes to the economic possibilities. Instead of renting diesel generators, another option is that they can rent mobile solar generators (see Appendix 2). However the price for renting is not known to us, the only possible mobile solution found has to be shipped all the way from America which is why we don’t account on it being feasible.

Even though wind and solar energy proposals may improve the festival’s competitiveness appealing to the environmental audience, there is a risk that the festival ticket price might increase or there will have to be made compromises in relation to the music bands invited, or alike, due to the huge investment costs in these technologies. This is a factor which will affect the festival’s competitiveness.

8.2.3 Performance

Performance is another relevant aspect. Securing the guests with electricity for warm food, cold beverages and other uses is indispensable. Biogas is considered a stable and reliable energy source as the amount of biogas is merely dependent on the amount of waste and human manure. The problem however is that the biogas needs 14-40 day to be generated so it cannot meet the needs of the guests during the festival itself.

Biodiesel is a substitute for the diesel in the generators, so reliability is not a problem here as the generators will work like they normally do.

Solar energy systems has the disadvantage that the energy from the daylight would need to be stored for the night uses, as many of the concerts and activities take place after sunset. Another drawback is that the weather is unpredictable and even though solar generators can work with only limited amount of sun, the reliability of the energy supply could easily be hindered if the 7 days turn out to be cloudy. Wind energy is as such a more reliable source, as wind is always present to some degree. However also here is the reliability of the energy system dependent on the weather conditions within the week the festival operates. A hybrid solution might solve the reliability problem to some extent, but wouldn’t solve the problems of cost.

8.3 Solution proposal

As analyzed above, it is difficult to suggest one solution alone, as none of the proposals meet all requirements. The final solution proposal will therefore suggest a combination of biogas and biodiesel in order to achieve the most significant environmental benefits. Biogas is an ideal solution to solve the waste problems, as it reuses the organic waste to produce energy, and even though it doesn't close the system in regard to the festival, the energy is not wasted but reused in the industrial system why the goals of industrial ecology is still achieved to some point.

To solve the problem with the emissions from the generators we therefore suggest to use biodiesel in relation with biogas, as it presents a good option to neutralize CO2 emissions and ensure enough energy supply for the festival users without being an enormous cost.

Both solutions together do not require investment costs, are environmentally attractive and in combination, they are able to meet the festival framework of both performance and consumer demand. Unfortunately none of the suggestions are directly apparent to the guest, which is why we also suggest that the initiatives are highlighted on cups and alike. Furthermore the money earned from selling the biomass, can be used to buy or invest in renewable energy solutions. Instead of exchanging all generators on the festival area, experiments with exchanging a few or parts of it could be done to highlight the initiative as well, but exchanging all the generators seems to be an enormous cost for the festival. Fireflysolar.co.uk furthermore even rents out small stages, which can be set up to state an example as well.

9. Conclusion

Europe houses more than 30 festivals each year which are similar to size of Roskilde. They all have in common that they last for only a short period of time. This puts enormous constraints on their ability to invest in the usual environmentally friendly solutions, such as buying wind or solar energy. However, what we have gained from this project is that is it definitely possible to improve the environmental situation significantly, either by minimizing the toxic wastes by changing to more environmentally friendly solutions and/or reusing it as energy in a biogas plant.

As shown in this paper, the proposals can be numerous to improve the environmental impact of festivals if research is done and if one is able to be open to the possibilities available. Biogas has as shown to be one of the solutions with the most potential as it solves the problem of waste generation, it does not mean an extra cost as it probably even would generate an extra income for the festival. Biogas cannot exchange the diesel generators and can thereby not close the loop as prescribed in Industrial Ecology. However, the extra income from selling the biomass can give some air in the budget to rent or even invest in other renewable energy devices or to simply substitute the diesel with biodiesel. Therefore our suggestion is to use the potential in the biogas in combination with some of the other mentioned renewable energy systems, where we have found biodiesel to be the most feasible solution.

Regarding the human manure, it is definitely possible to use it as biogas, and the potential of using the manure to generate biogas even increases immensely when it is mixed with other organic waste materials from the festival. However, regardless of the enormous potential in the biogas, it cannot be overlooked, that the biogas plants are not able to use human manure at this point due to the difficulties of using the resulting soil on agricultural fields. It first needs to be politically excepted before the potential can be fully possible.

10. Perspective

The environmental goals which were prioritized in this project were waste recycling and reduction of CO^2 emissions, however other initiatives could be taken to make Roskilde festival “greener”. Some ideas on how the project could be expanded will shortly be presented here.

Establishing an energy saving plan for the entire festival could be one way to further improve the environmental impacts, thereby reducing the overall amount of diesel/biodiesel or grid electricity needed. The plan could include an analysis of the cooking equipment used in the agoras, which might be old and ineffective. New light technologies on the stages, which could be substituted by more effective and energy saving diode light, could be another possibility. They are more expensive than normal lights, but have a longer lifetime and a significantly less energy consumption. Such an energy saving plan would achieve that the alternative energy systems would need to substitute a lesser amount of energy and thereby also save money for the festival which could then be used for other environmental initiatives.

The waste separation at the festival is advanced in compared to other festivals, however, improvements in this sector are still possible. If the organic waste is separated correctly from the rest, the biogas potential increases. An advanced waste separation plan for the festival could be another positive contribution to reduce negative impacts on the nature. Furthermore festival guests could be motivated to be more aware of their waste disposal to enhance their environmental awareness. One idea could be to investigate how the festival can use the opportunity of hosting a large crowd of young people to increase awareness and motivate them to take actions against pollution. This could be done through fun activities, competitions or certain “green areas” where games in relation to new technological innovations are played and where people have a chance to be inspired and share their ideas.

Another important investigation in relation to the analysis of this report could be too look at the political and social difficulties in using human manure for energy production and the byproduct as fertilizers. A difficulty is that some companies refuse to buy food from agricultural fields were human fertilizers has been used, however the energy potential in using the human waste products is very high, therefore is it important to find a way to delimit any barriers regarding the possibility to use this energy to substitute fossil fuels.

Other outdoor music festivals are most likely facing similar problems to the Roskilde festival, a general plan on how the ideas given here could be applicable to other European festivals could help improving the environmental impacts resulting from these types of human activities.

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APPENDIX 1

http://www.roskilde-festival.dk/2009/frontpage/specialmenu/for_the_media/nice_to_know/

NICE TO KNOW

Where do the guests come from? What are the stages called? How much money do the guests spend during the festival? Roskilde Festival is full of fun trivia. Below you can find some of this trivia – maybe even some useful facts.

WHAT ARE THE STAGES CALLED – AND HOW BIG ARE THEY?

Stage	Capacity/Audience	Trivia
Orange Stage	60,000	Consists of app. 1.100 m² tent canvas and 1.086 m² stage floors inclusive Bay ect. The tent weighs 3.5 tons. The two big screens on either side of the stage are 32 m² each. There is 384.000 watts light on the stage and 168.000 watts light among the audience. Additionally, there are 92 so-called moving heads on stage and 40 among the audience. The sound system has a total capacity of app. 200.000 watts including delay.
Arena	17,000	Consists of 4.932 m² tent at standing height and 654 m² stage floors. The complete tent area is 6.450 m².
Odeon	5,000	Consists of 1.922 m² tent and 409 m² stage floors.
Cosmopol	6,000	Consists of 2.950 m² tent at standing height and 334 m² stage floors. The complete tent area is 3.468 m².
Astoria	3,000	Consists of 2.660 m² tent and 404 m² stage floors.
Pavilion / Pavilion Junior	2,000	Consists of 1.134 m² tent and 264 m² stage floors.
Lounge	1,200	The stage has a size of 176 m².The floor is covered with app. 60 tons of sand.

WHO IS THE AUDIENCE – AND WHERE DO THEY COME FROM?

The festival area in total: 75.000 tickets sold in advance + 4.000 press representatives + 3.000 artists and 25.000 volunteers. In addition Sunday guests (including free tickets for senior guests (60+), Sunday tickets and children)

- 50 % are women, and 50 % are men.
- 70 % have been to Roskilde Festival more than once.
- 80 % of the guests are 18-28 years old and the average age is 24 years.
- 50 % of the guests arrive on the opening Sunday.
- 50 % of the guests arrive by car.

WHAT COUNTRIES DO THE GUESTS COME FROM?

Denmark 54 %
Norway 18 %
Sweden 16 %
Germany 2 %
England 4 %
Rest of the world 6 %
(numbers from 2007)

HOW MANY HAS PARTICIPATED IN THE FESTIVAL DURING THE YEARS?

Year	Number of guests	Ticket sales	Ticket price
1971	10.000	3.000 tickets sold	30 DKK
1976	32.500	x	60 DKK
1978	36.500	x	100 DKK
1983	60.600	x	200 DKK
1987	58.700	x	320 DKK
1992	64.500	x	540 DKK
1996	115.000	90.000 tickets sold	700 DKK
1998	100.000	75.000 tickets sold	810 DKK
2000	102.000	76.000 tickets sold	860 DKK
2001	92.000	64.000 tickets sold	860 DKK
2005	97.000	65.000 tickets sold	1250 DKK
2006	110.000	80.000 tickets sold	1350 DKK
2007	110.000	77.000 tickets sold	1475 DKK

WHO ARE THE VOLUNTEERS – AND HOW MANY ARE THERE?

Number of volunteers in total: 25.000.

App. 6.500 people work for Roskilde Festival. Others volunteer through service- and trade associations.

Roskilde Festival has an ambassador network abroad, which consists of 413 dedicated Roskilde-fans who volunteer for Roskilde Festival in 17 European countries.
(numbers from 2007)

HOW BIG IS THE FESTIVAL AREA?

Festival area as such: 162.000 m²
Closed areas: 189.600 m²
Camping, incl. Camping South: 779.000 m² (not including agoras and non-inhabitable areas).
Parking: 300.000 m², of which 50.000 m² is closed parking.

In total: 1.438.222 m² (Ccrrespond to app.200 football fields)

The whole area is encircled by 32 kilometers of fence, which is held up by app. 9.200 fence posts.

There are 14 kilometers of network cable for telephone, internet, credit cards etc.

(Based on numbers from 2006)

ENVIRONMENT AND SANITATION

There are 2000 garbage bins at the festival area - and the amount of garbage bags used per festival is app. 200,000 bags.

Total amount of garbage from the festival in 2007: app. 3,000 tons (90 % inflammable). Every festival guest leaves behind app. 40 kilos of droppings.
Up to 97 % of the plastic cups, which the beverage stalls hand over the counters, are returned through the deposit points.

In 2007, the guests collected 13.7 tons of garbage – in exchange for cold beer.

Approximately 10,000 m3 (10 million litres) of water is used in the course of a festival.

The festival use app the total of 400,000 kwt in a week.

Recycling collection: During the last three years app. 10.000 sleeping bags together with 1.200 roll mats have been collected. It has all been donated to homeless people in Copenhagen through the charity organisation Koefods kælder.

Environmental labels: All the festival posters, flyers and prospectus are all printed on eco-labeled recycled paper. Also all the toilet paper is eco-labelled.

In 2007, the festival guests produced approx. 5 kg garbage per day.

One of the world's longest urinals can be found at Roskilde Festival: it is 850 meters long.

Cutlery and tableware: The audience is both hungry and thirsty. In 2007 they used: 851,000 napkins, 347,000 forks, 189,000 knives, 127,000 soup plates, 191,000 plates, 308,000 coffee cups, 304,000 soda coups and a total of 804,000 beer cups and 391,000 paper pockets for burgers.

AND WHAT DO THEY SPEND THEIR MONEY ON?

Roskilde Festival's working budget: app. 120 mio. kr.

The guests at Roskilde Festival generate more than 300 million kr. in Roskilde and the surrounding areas.

- In 2008 Roskilde Festival is held for the 38th time.
- 75,000 tickets are on sale, and the ticket price is DKK 1,650 (€ 220). Tickets include all 8 days together and camping – and are not sold for single days (except for Sunday when a one-day ticket can be bought for DKK 750 (app. € 100).
  The audience comes from all over the world – and again in 2008 more than 50 % are expected to be from other countries than Denmark.
- In total, approx. 175 bands are expected to play at Roskilde Festival's 7 stages.
- Roskilde Festival is organised by The Roskilde Festival Charity Society – a society whose purpose is to collect money to humanitarian and cultural work. Any profit that the society earns from Roskilde Festival is donated to charity. A total of DKK 100 million has been donated throughout the years.
- Roskilde Festival is arranged on the basis of committed volunteers. More than 25,000 volunteers create the unique Roskilde Festival service, quality and atmosphere.

Appendix 2

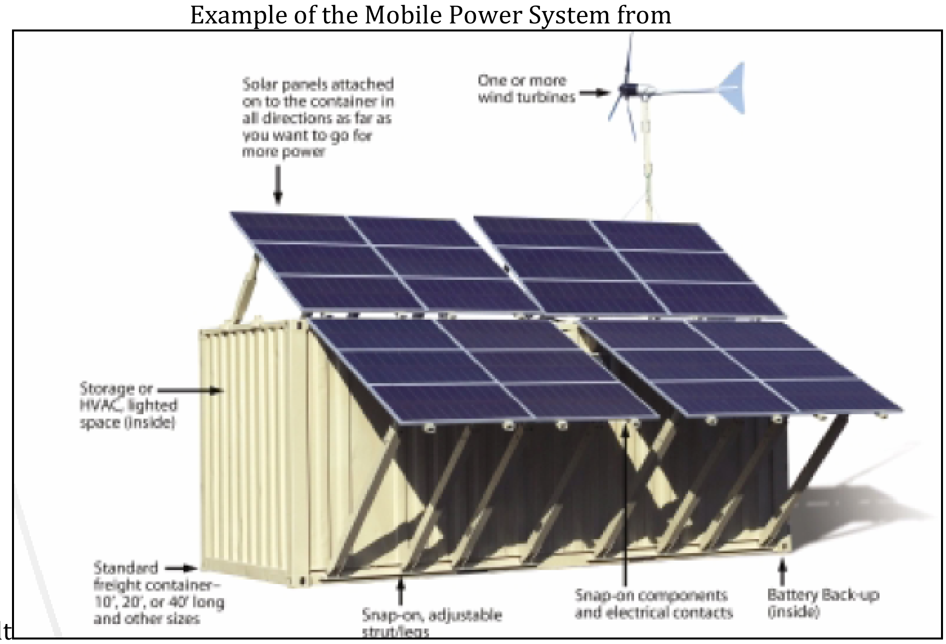
Source: www.fireflysolar.co.uk and www.skybuilt.com.

There are several transportable devices available for renting which can exchange the diesel generators. Firefly Solar's Orion and Skybulits Mobile Power Station (MPS) are given as examples.

The firefly solar can produce a maximum of 2kW pr. unit[1] where the MPS can generate up to 50kW pr. container[2]. Each has energy storage possibilities, making the unit able to run at night. The MPS furthermore has a backup generator attached which can run on either diesel og biodiesel, and the possibility to generate power from the wind via. attachable windmill devices – making it what we call a hybrid system in the report. Both take up a relatively huge amount of space ranging from $4m^2$ pr. kW for the MPS to $16m^2$ pr. kW for the Firefly Solar.

Both of the systems are found abroad as we haven't been able to find good alternatives in neither Denmark, Norway, Sweden or Germany. The firefly solar system needs to be transported from England and the MPS needs to be transported all the way from Washington, USA. This transportation is a major drawback in relation to the CO2 emissions saved using the devices. The prices for the Orin Device is ___ and the price for the MPS is ____ transportation costs not included.

Example of the Mobile Power System from



Skybuilt

[1] Each unit comes in a trailer, containing 16 panels, each with a footprint of $2m^2$.

[2] When it is attached with wind energy as well.

Appendix 3

Source: http://www.zephyreco.co.jp

A Japanese company offers the lightest wind turbine in the world. The main ideal of design air dolphin is to mimic fish swimming and use the same principle to against the bafflement from the strong winds. This product is of 16 kg weight but with high conversion efficiency from wind to electricity. This small size solve the area problem which means it fits in most condition as it can just be placed on top of a roof. The new technologies of this design are to offer the solutions of durability, noise, vibration and aesthetic.

The minimum operation possibility is 2.5 meter per second (m/s) and the maximum capacity is 50 m/s. The continuous rate output is 1kW which is enough to support a small area like bar or cooking stand. The light glades use few seconds to start-up the rotor which could cumulate more wind power and produce more electricity. The special innovations for the blades make lower noise and low vibration. All of these merits fix the disadvantage side. And the cost of each product is around 50,000 DKK.[1]

[1] http://www.zephyreco.co.jp/en/main_pro_airdolphin.htm#top