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MSc Program
Renewable Energy in Central and Eastern Europe

Technical and financial feasibility of hydrothermal carbonization for the conversion of biowaste

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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24.04.2012, Vienna

Affidavit

I, **Dipl. Ing. mont. Dr. Walter TESCH**, hereby declare

1. that I am the sole author of the present Master Thesis,
"Technical and financial feasibility of hydrothermal carbonization for the conversion of biowaste", 108 pages, bound,
and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

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Date Signature

Abstract

Hydrothermal Carbonization (HTC) is a thermochemical process for the conversion of organic substances to a hydrophobic solid of reduced mass and increased fuel value. The main subjective of this master thesis is to evaluate the technical and financial feasibility of the HTC-process for the implementation into an existing compost plant. It is shown, that this emerging technology is already technically and financially feasible if implemented into an existing infrastructure. Additional research and development is still need for optimization of this process especially with regard to a continuous operation of a plant of industrial scale.

However, hydrothermal carbonization has a great potential not only for the treatment of organic waste, but for a green and sustainable production of highly functionalized carbonaceous materials for the application in the fields of catalysis, adsorption and energy storage.

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1 Introduction

For many decades, Europe has enjoyed growth of wealth and wellbeing, based on intensive use of resources. Worldwide the fossil fuel use increased by a factor of 12 over the 20th century, whilst extracting 34 times more material resources. Today, sources of energy, minerals and metals, as well as water, fertile soil, biomass, biodiversity and others are all under pressure, as is the stability of the climate system. 60% of the world's major ecosystems that are the basis for the production of food, feed and fiber have already been degraded or are used unsustainably (Global2000 2011, European Commission 2011).

While some people already worry about peak oil and the end of cheap energy, it seems that other resources are "peaking" even faster. Globally, about 24 billion tones of fertile soil erode every year. Worldwide soil erosion was estimated in 1995 to cost in the order of EUR 300 billion a year (Myers 1996).

Based on assumptions of the World Business Council for Sustainable Development (WBCSD), we will need to increase our resource efficiency by 4 to 10 times till 2050, with some significant improvements till 2020 (WBCSD 2008, Weizsäcker 2009).

In order to address the issue of resource efficiency, the European Commission implemented the Europe 2020 Strategy with its flagship initiative on "A Resource Efficient Europe" (European Commission 2011). Based on this initiative a roadmap has been developed "to define medium and long term objectives and means needed for achieving them". This Roadmap is coordinated with other initiatives under the mentioned flagship initiative of the European Commission, in particular the policy achievements towards a low carbon economy. In addition, this Roadmap takes into account the progress made on the 2005 Thematic Strategy on the Sustainable Use of Natural Resources (European Commission2005) and the EU's strategy on sustainable development. The Roadmap perfectly fits into other worldwide efforts to achieve a transition towards a green economy[1].

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[1] For instance OECD's Green Growth Strategy, UNEP's Green Economy report and the work done by the European Environment Agency.

Following vision has been defined by the European Commission (European Commission 2011):

> *The Vision: By 2050 the EU's economy has grown in a way that respects resource constraints and planetary boundaries, thus contributing to global economic transformation. Our economy is competitive, inclusive and provides a high standard of living with much lower environmental impacts. All resources are sustainably managed, from raw materials to energy, water, air, land and soil. Climate change milestones have been reached, while biodiversity and the ecosystem services it underpins have been protected, valued and substantially restored.*

In order to realize this vision, the European Commission has defined several milestones to be achieved. Amongst them are two milestones regarding waste, as well as land and soil (European Commission 2011):

The milestone for turning waste into a resource is defined as:

> *Milestone: By 2020, waste is managed as a resource. Waste generated per capita is in absolute decline. Recycling and re-use of waste are economically attractive options for public and private actors due to widespread separate collection and the development of functional markets for secondary raw materials. More materials, including materials having a significant impact on the environment and critical raw materials, are recycled. Waste legislation is fully implemented. Illegal shipments of waste have been eradicated. Energy recovery is limited to non recyclable materials, landfilling is virtually eliminated and high quality recycling is ensured.*

The milestone for land and soils is given as:

> *Milestone: By 2020, EU policies take into account their direct and indirect impact on land use in the EU and globally, and the rate of land take is on track with an aim to achieve no net land take by 2050; soil erosion is reduced and the soil organic matter increased, with remedial work on contaminated sites well underway.*

In this document a new biomass conversion process called hydrothermal carbonization (HTC) is presented, which has the potential to convert biomass currently defined as organic waste into a secondary raw material to provide at least renewable energy and/or increase soil organic matter. Thus, this biomass conversion process described is fully in line with the "Roadmap to a Resource Efficient Europe."

1.1 Motivation

In order to understand the customer's needs and to find proper solutions, ILF has to stay up to date with the development of new technologies regarding renewable energy. Hydrothermal carbonization has the potential to convert any kind of biomass to a hydrophobic solid of reduced mass and increased fuel value. The HTC process is actually in a phase to become marketable. This is usually the phase where ideas have to be supported by engineering knowledge and experience in order to be successful. Thus, it is the intention of this thesis to provide the necessary information for ILF in order to formulate a proper strategy regarding HTC and help our customers to implement this technology into their processes.

1.2 Core Objective

The core objective of the study is to review the technical and financial feasibility of hydrothermal carbonization for the conversion of biowaste. This shall be done by reviewing the HTC process to understand better the following items:

- Mechanism of the conversion reaction.
- Possible feedstock.
- Possible process technologies (batch, continuous, semi-batch).
- Boundary conditions for financial feasible implementation (feedstock price, product price, subsidies…).

1.3 Citation of main literature

Following main literature has been the basis of this work:

- Titirici M.-M., Antonietti M.: Chemistry and materials options of sustainable carbon materials made by hydrothermal carbonization. Chem. Soc. Rev. 39, 103–116, 2010.
- Ramke H.-G., Blöhse D., Lehmann H.J., Antonietti M., Fettig J.: Machbarkeitsstudie zur Energiegewinnung aus organischen Siedlungsabfällen durch Hydrothermale Carbonisierung. Deutsche Bundesstiftung 2010.

1.4 Structure of work

The conversion of biomass by hydrothermal carbonization is quite new in the biomass-sector. Thus, a general introduction into this process is given in the first part of the master thesis.

In the second part the technical and financial feasibility of the HTC-process for the conversion of municipal biowaste is analyzed using a case model based on an existing compost works in Lower Austria.

2 Description of Methods

2.1 HTC Process Background Information Research

In order to get an overview on the theoretical background of the hydrothermal carbonization process, following approaches have been made:

- Literature research in scientific journals and internet.
- Direct contact and interviews with suppliers of HTC process plants.

Peer reviewed papers have been identified using the internet portal “science direct”. In addition, presentations and other publications, which have been provided by the authors on the internet for free, have been used as basis for information too.

Complementary to the research of the scientific background of the HTC process, suppliers of HTC process plants have been contacted to get an impression on the current marketability of this biomass conversion technology. For this purpose a standardized questionnaire has been developed and sent to potential suppliers. A template of the questionnaire is provided in ANNEX 1.

2.2 Evaluation of Technical and Financial Feasibility

2.2.1 Technical feasibility: Methodology

For the evaluation of the technical feasibility of the HTC process for the conversion of biomass/biowaste to a marketable product, a case model has been developed based on an existing compost works.

In a first step the necessary process plant parameters where defined followed by the general definition of the plant units necessary to realize the process. The technical setup was finally defined by implementing the general process unit setup into the existing infrastructure of the compost works.

2.2.2 Financial feasibility: Methodology

Based on the technical findings a Financial Analysis has been made. The objective of the Financial Analysis is to assess the financial viability and sustainability of the project over the entire project lifetime. The concept of the Financial Analysis shall not be mixed up with an Economic Analysis. There are substantial differences between an Economical and Financial Analysis. Whereas the Financial Analysis considers all accruing expenditures and revenues of the whole project, an Economic Analysis is accomplished from the viewpoint of the national economy. Thus, the Financial Analysis is accomplished on a nominal basis, i.e. taxes, fees, duties and inflation are taken into account. Within the scope of this master thesis only the described financial analysis has been made.

The financial evaluation of the project has been made according to the methods of a cash flow analysis. The study has been carried out using a spreadsheet model developed specifically for use in project financing studies of power projects. This financial model is highly flexible and allows a wide range of input variables to be independently specified. Thus it summarizes and reflects technical combined with financial input.

The financial analysis has been elaborated with a semi-annual model based on Microsoft Excel. The goal was to evaluate the cash flows over a project period of 20 years and to determine the impact of changes in different input parameters on the internal rate of return (IRR) of the project. The financial analysis of the Case Study has been based on the following steps:

- Estimation of Capital Expenditures (CAPEX)
- Estimation of Operating Expenditures (OPEX)
- Identifying expected costs and revenues
- Valuing the costs and revenues
- Calculation of the main financial indicators.

The estimation of Capital Expenditures (CAPEX) and Operating Expenditures (OPEX) have an accuracy of + 10% / -10% and has been developed also from comparative costing using key indicators such as capacity, complexity, conversion rate, manning scheme, etc.

The CAPEX estimation includes estimations on future engineering phases, process licenses to be obtained, site preparation, construction costs, etc. and are supported by ILFs extensive experience.

The estimated amount of revenues is linked to the anticipated received amount of organic waste and achievable selling price for the HTC-products.

The results of the financial analysis are profitability and bankability indicators.

The profitability of a project is its capacity to generate an adequate level of profitability of the invested capital versus private investors' expectations. The indicators which have been used are, inter alia, Financial Net Present Value (NPV), Financial Internal Rate of Return (IRR), Financial Return on Equity (ROE), Payback Period (PP).

The bankability of a project is its capacity to generate sufficient cash flows to guarantee debt payment. The indicator which has been used is the Debt Service Cover Ratio (DSCR).

Since the model is based on future cash inflows and outflows (i.e. forecasted cash flows) it requires numerous inputs some of which are known but most of them are uncertain and based on estimations. Usually, an analyst provides a single figure for the used indicators – e.g. IRR, NPV etc. - but it is always unclear what the probability of this single outcome is. Therefore, in addition to the elaboration of the usual financial indicators, an interval analysis was performed in this master thesis which results in a range of the selected indicators.

The following input parameters or constraints form the base for the financial analysis:

- Calculation Method
- Projection period
- Feedstock processing capacity
- Feedstock composition
- CAPEX
- OPEX
- Contingencies CAPEX
- Contingencies OPEX
- Acceptance price
- Product price
- Inflation and escalation rate (e.g. for utilities, personal costs…)

- Debt to equity ratio
- Discount factor
- Corporate tax

A detailed overview of the input parameters for the base case is given in ANNEX 2.

Following financial parameters have been elaborated (after taxes) to evaluate the financial feasibility of the project:

- Internal rate of return (IRR) on capital (equity + debt)
- Net present value (NPV) on capital (equity + debt)
- Simple payback period on capital (equity + debt)
- Average and minimum debt service cover ration (DSCR)
- Break even for positive IRR on capital regarding product price

Based on the sensitivity and elasticity analysis of the usually used indicators (IRR, NPV…) an interval of likely estimates is given for each of the decisive input parameters. This means that instead of estimating the parameters by a single value, a range of values – i.e. from an optimistic to a pessimistic boundary - is assumed in the Financial Analysis.

For this reason, three different scenarios have been elaborated:

1. The first case presents the “normal, middle-of-the road” (“mean”) case. The assumptions made are the best guess currently possible and should be the most realistic ones also.
2. The second case reflects the “best case”. As the realization of the project would be the first in Austria it has been assumed, that a non-repayable funding of 25% of the total investment costs (without contingencies) is possible. In addition, an optimistic HTC-coal price given by vendors of HTC-process plants and the possibility to sell CO2 certificates have been taken into account.
3. The third case describing a “worst case”, is based on the “middle of the road” scenario, but HTC-coal prices are set to the ones comparable to wood-pellets in Austria . For comparison, the HTC-coal price has been calculated based on it’s estimated lower heating value.

2.2.2.1 Sensitivity Analysis and Elasticity

The financial feasibility of this project relies on several forecasts and assumptions. The purpose of the sensitivity analysis is to identify project parameters which have the potential to affect project results in an adverse manner. It shows the effects of variation in key parameters on the “financial results”. The approach used in the sensitivity analysis was to vary each sensitivity parameter by a certain percentage and to calculate the resulting effect on the IRR.

Following main sensitivities have been analyzed for the case model:

- CAPEX (-10%/+10%)
- OPEX (-10%/+10%)
- Product yield (-10%/+10%)
- Acceptance price for organic waste (-10%/+10%)
- Product price (-10%/+10%)
- Investment Funding (yes/no)

The results of the sensitivity analysis are presented graphically as “Net Diagram”.

In addition, the elasticity of the elaborated sensitivities has been elaborated. The elasticity analysis aims to identify the relative effects of the changes triggered by the sensitivity analysis compared to the respective sensitivity factor. Thus, the sensitivity analysis gives an indication, if the variation of a certain parameter results in a proportional or antiproportional effect and if this effect is not significant, meaningful or overproportional. The graphical interpretation of the elasticity results have been plotted in a so-called “Tornado-Graph”.

3 Theoretical Background HTC

3.1 History

The first scientific, successful experiments regarding hydrothermal carbonization have been performed at the beginning of the 20th century. Friedrich Bergius and his colleagues at the Hanover Institute of Technology studied several reactions under high pressure. It was the time when high pressure synthesis became industrialized by e.g. establishing the Haber-Bosch process for the production of ammonia.

During his studies he observed that the treatment of peat in the presence of liquid water released considerable quantities of carbon dioxide at temperatures above 300°C, and that the composition of the powdery residue was close to that of natural fat coals. The possibility to gain coal, which has been the main economic driver of this age, from organic substances by reproducing the gradual transition of organic matter into bituminous coal within hours instead of millions of years, lead to a systematic analysis of this process. Bergius reported his results 1912 in a monograph (Bergius 1912). Friedrich Bergius finally received for his work the Nobel Prize in Chemistry on May 21, 1932 (Bergius 1932).

Although, several studies have been performed on the synthesis and characterization of coal, it got buried on oblivion with the emerging of the oil age. However, during the first decade of this century the hydrothermal carbonization process has been rediscovered and further scientifically analyzed by Markus Antonietti at the Max Planck Institute of Colloids and Interfaces in Golm (Antonietti 2009, Titirici 2007).

3.2 Biomass Conversion Processes

The conversion pathways of biomass to energy can be performed in several ways, depending not only on the type of biomass, but the desired product also. These processes can be divided into three groups: Thermo-chemical, Bio-chemical and Physico-chemical reaction pathways as shown in Figure 1 (Kaltschmitt 2009).

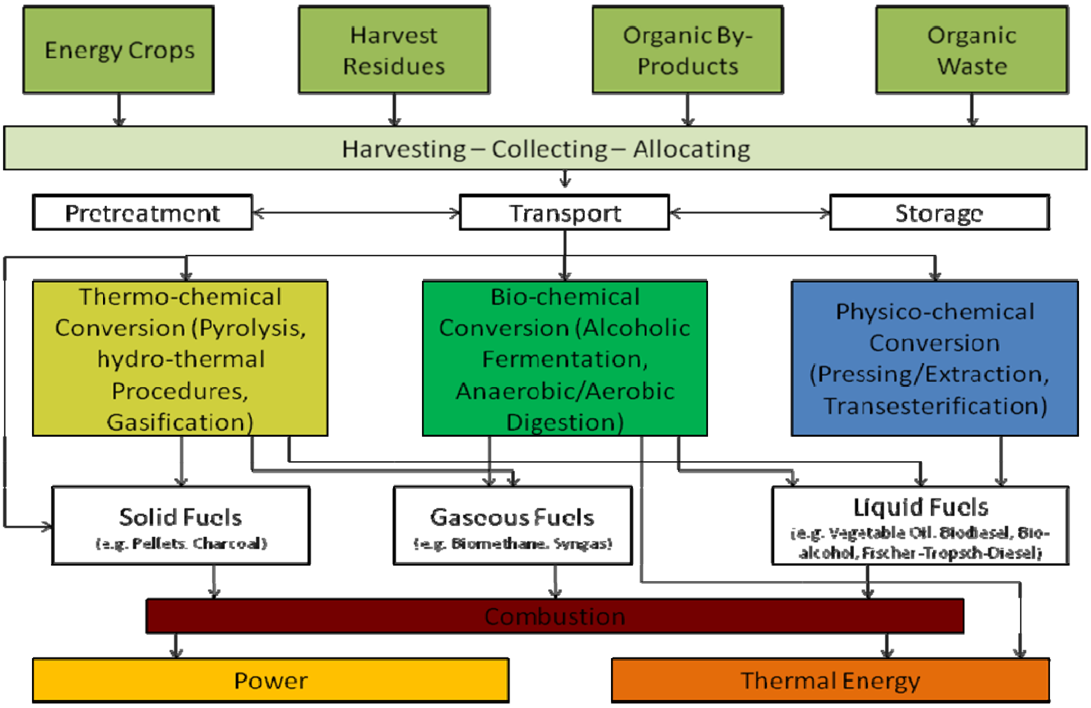


Figure 1. Biomass conversion pathways (according to Kaltschmitt et al. 2009).

Physico-chemical methods are mainly the extraction of vegetable oils using pressure and transesterification of e.g. rape oil to produce rape-methylesters, which are more or less the first generation biodiesel products. Using bio-chemical conversion methods, biomass is disintegrated to intermediates by chemical or enzymatic processes. In a further step these are converted to ethanol by fermentation leading to bio-gasoline.

As shown in Figure 1, hydrothermal carbonization is part of the thermo-chemical processes. Thermo-chemical processes can be distinguished mainly by the resident time of the biomass in the converter, conversion temperature and the excess of oxygen (Figure 2).

Another parameter is pressure. While most of the thermo-chemical processes are performed at atmospheric or low pressure (< 1 bar(g)), for hydrothermal processes pressures between usually 10 to 300 bar(g) are necessary in order to prevent the water to make a phase transformation to steam.

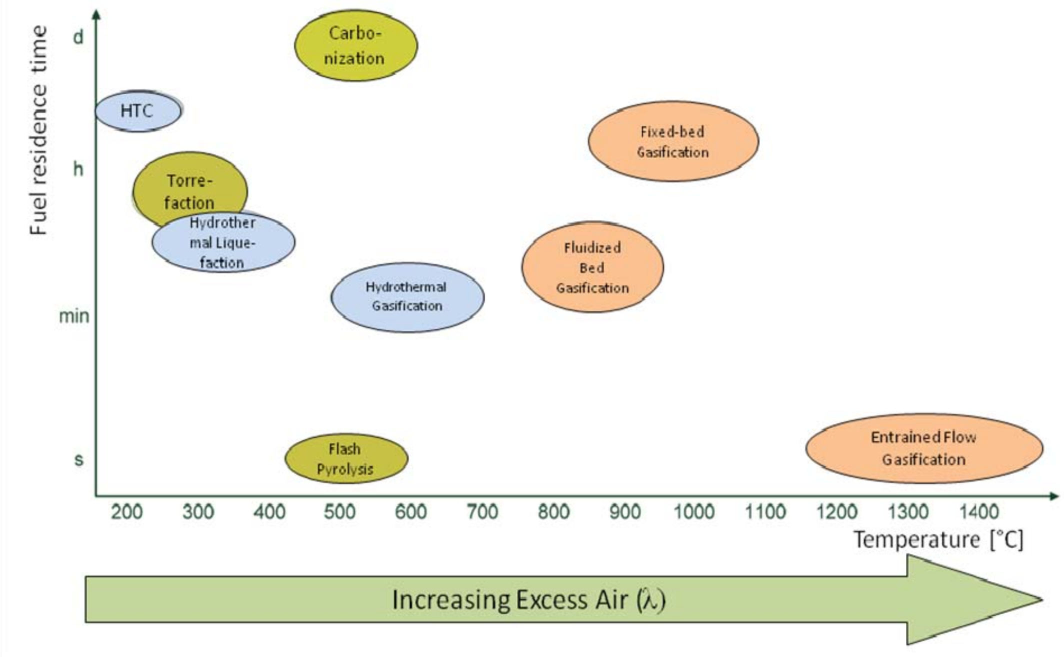


Figure 2 Main process conditions of typical thermo-chemical conversion pathways (source: Ortwein 2010).

3.3 Hydrothermal Processes

Hydrothermal processes can be generally distinguished by the aggregate state of the final product (solid, liquid, gaseous). Table 1 gives an overview on the typical hydrothermal processes.

Table 1. Hydrothermal processes (Source: Ortwein 2010, Heilmann 2011).

	Hydrothermal Carbonization	**Hydrothermal Liquefaction**	**Hydrothermal Gasification**
Reaction medium	Water (liquid)	Water (liquid)	Water (near/above supercritical)
Typical temperature range	170 – 250 °C	250 – 350 °C	350 – 380 °C / 600 – 700 °C
Typical pressure range	10 – 20 bar(g)	50 – 200 bar(g)	180 – 300 bar(g) / 250 – 300 bar(g)
Typical catalyst	Citric acid or $FeSO_4$	Alkalicarbonates, alkalinehydroxides	Ru, Ni / none
Typical reaction time	4 – 16 h	10 – 15 min.	<1h / 1 – 5 min.
Main products	Coal-suspension, coal-granulate	Phenol rich, oily liquid	Hydrogen, carbon dioxide, methane
Product separation	Filtration and drying	Phase separation hydrophobic/ hydrophilic	Phase separation gaseous/liquid

In the last decades the main focus has been on the hydrothermal liquefaction and gasification of biomass in order to gain liquids and/or product gas for the application as biofuels (Peterson 2008). Markus Antonietti at the Max Planck Institute of Colloids and Interfaces in Golm rediscovered the hydrothermal carbonization of biomass starting a new hype in this field (Titirici 2007, Antonietti 2009, Titirici 2010).

3.4 Hydrothermal Carbonization

The basis for hydrothermal carbonization of biomass are the same reactions as nature uses to convert biomass via peat to black coal within hundreds (for peat) to millions (for coal) of years. This process can be illustrated in a simplified way using the van Krevelen diagram. Van Krevelen diagrams are graphical plots developed by Dirk Willem van Krevelen and used to show the thermocatalytic maturation pathways of different organic matter to produce kerogen and petroleum. The diagram given in Figure 3 shows the atomic ratio of hydrogen to carbon (hydrogen index) as a function of the oxygen to carbon ratio (oxygen index) (Behrendt 2006). As illustrated in Figure 3 the carbonization of cellulose and wood happens along the path via peat, lignite, brown coal, anthracite coal to anthracite. Thus the process can be described within these diagrams form upper right to lower left.

Although the hydrothermal carbonization does not take centuries to convert biomass to coal, it is slow enough to give to possibility to interrupt the process from its upper right to the lower left in the van Krevelen diagram resulting in peat or humus-like product offering interesting possibilities as soil conditioner (Schuchardt 2010, Lehmann 2011, Wallmann 2011, Kamman 2011, Helfrich 2011, Funke 2011, Taylor 2010).

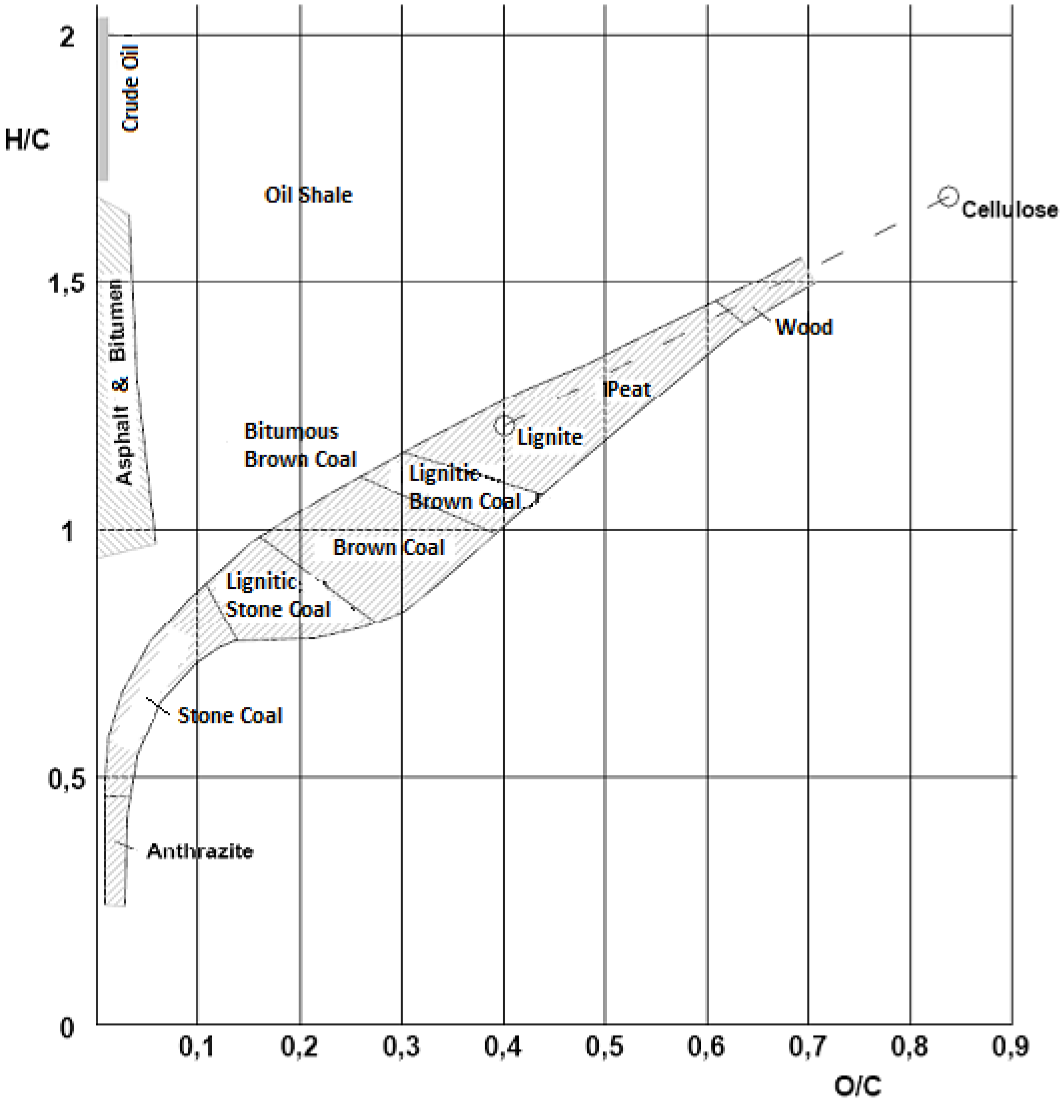


Figure 3. Van Krevelen plot showing the carbonization of cellulose (Source: Behrendt 2006).

In order to speed up this “coaling” process, there have been several experiments trying to chemically imitate the carbon formation from carbohydrates by using faster chemical processes. Hydrothermal carbonization has gained quite a lot of advertency over the last view years, as one of the most promising processes for this issue. Researchers in this new (rediscovered) field of chemistry are convinced that every kind of biomass can be treated by hydrothermal carbonization to produce a hydrophobic solid of reduced mass and increased fuel value.

3.4.1 Feedstock for the Hydrothermal Carbonization Process

Biomass suitable for the hydrothermal carbonization process range from cellulose-free micro-algae (Heilmann 2010) over lignocellulosic biomass like hard or soft wood, switch grass or miscanthus, to waste products from food production, such as rice hulls, corn stover, straws, distiller’s grains (Heilmann 2011), and organic wastes like sewage sludge, animal manure (Sun 2011), digestate (Mumme 2011) or leftovers (Ramke 2010). Even municipal solid wastes have been treated successfully in order to enhance the energy content per weight and especially per volume (Lu 2011, Berge 2011).

A quite comprehensive test series of possible feedstock has been performed by a research team headed by Professor Dr. –Ing. Hans-Günter Ramke of the Hochschule Ostwestfalen-Lippe - University of Applied Science in Höxter (Ramke 2010).

Figure 4 shows the potential feedstock based in different kind of wastes. Only the grey colored sources have been used for the study performed by Ramke et al.

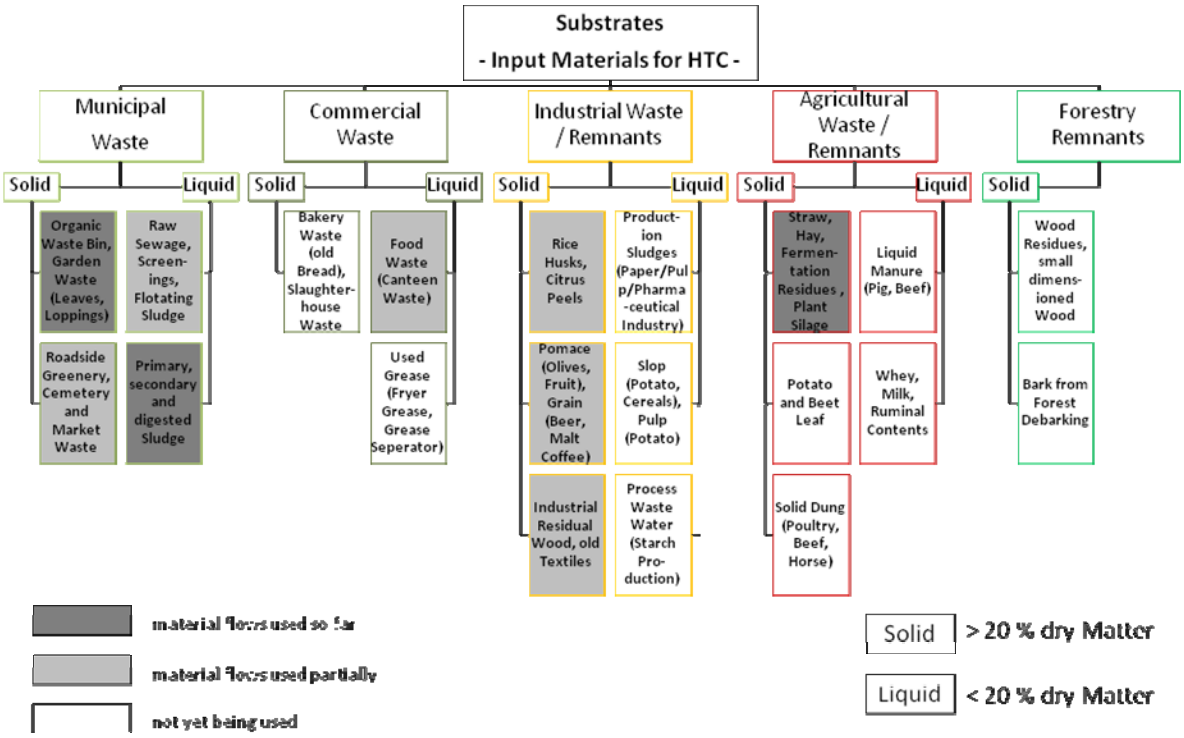


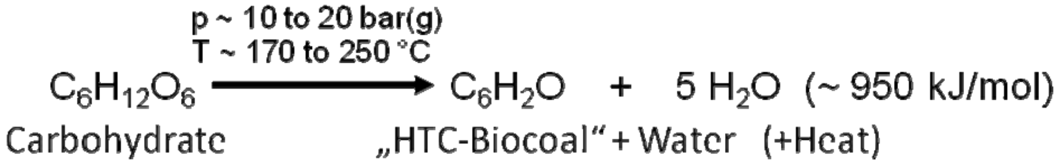
Figure 4. Potential HTC Feedstock (Ramke 2010).

However, as it gives a good overview on the variations of the physical and chemical properties of the biocoal in dependence on the feedstock, the main results shall be briefly shown in this thesis also.

3.4.2 General Process Conditions

Hydrothermal carbonization is usually performed in an autoclave at a pressure of 10 to 20 bar(g) and a temperature between 170°C to 250°C using water as reaction (and heat transfer) medium and avoiding any air (oxygen!). The reaction takes between 4 to 26 hours and results in some sort of slurry of small lignite particles in water.

The chemical reactions involved in the hydrothermal carbonization process are based on the dehydration of carbohydrates:



$$\underset{\text{Carbohydrate}}{C_6H_{12}O_6} \xrightarrow[]{\substack{p \sim 10 \text{ to } 20 \text{ bar(g)} \\ T \sim 170 \text{ to } 250\,^\circ\text{C}}} \underset{\text{„HTC-Biocoal“}}{C_6H_2O} + \underset{\text{+ Water}}{5\,H_2O} \quad \underset{\text{(+Heat)}}{(\sim 950 \text{ kJ/mol})}$$

Figure 5. Simplified chemical equation of hydrothermal carbonization (Source: Antonietti 2009).

More specifically, the three important steps of the chemical reaction are (1) dehydration of the carbohydrate to (hydroxymethyl)furfural (HMF), (2) polymerization towards polyfurans and finally (3) carbonization by further intermolecular dehydration.

As an example, the carbonization of wood shall be shown in more detail. The main components of wood are cellulose, hemicelluloses and lignin as shown in Figure 6. According to the von Krevelen diagram, lignin as such is already far more in the region of lignite, while the cellulose compounds are in the upper right of the diagram. Thus, the determining reaction pathway on the timescale is the conversion of cellulose to biocoal. Figure 7 shows a simplified comparison of the hydrothermal carbonization process of lignin and cellulose.

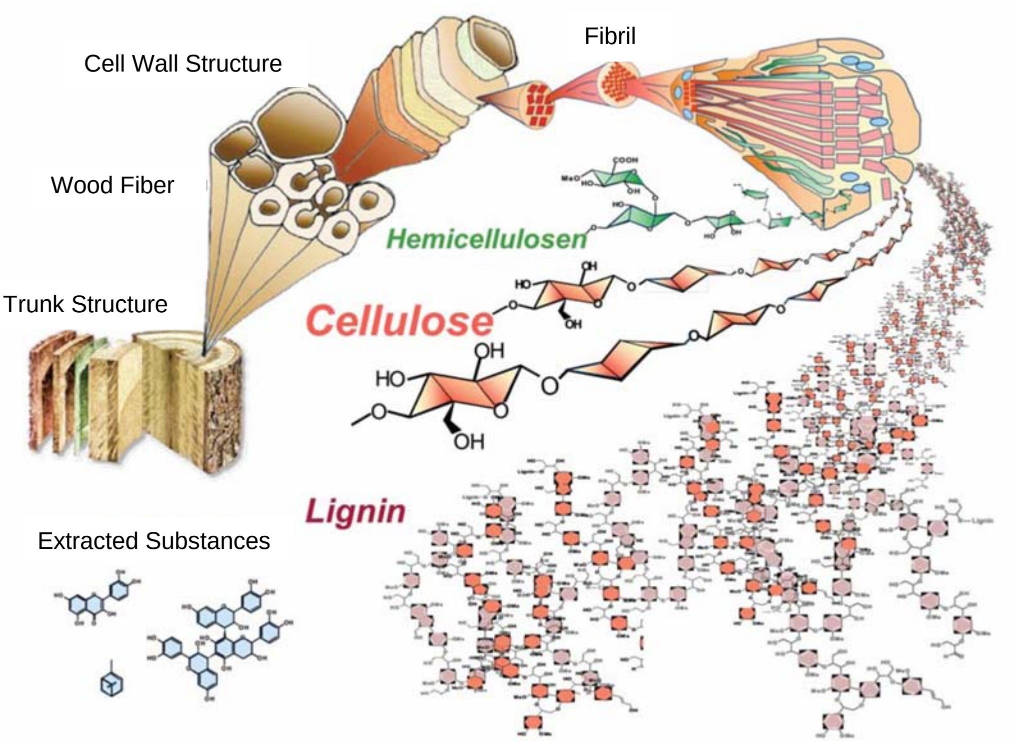


Figure 6 General structure of wood (Source: Meier 2009).

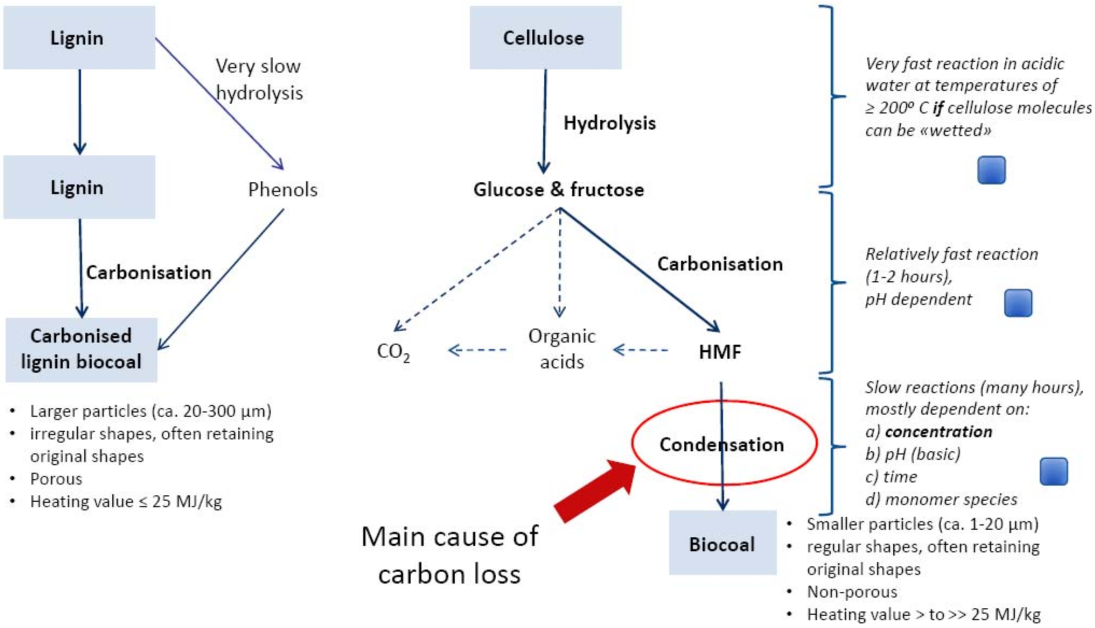


Figure 7. Simplified reaction schemes of lignin and cellulose (Source: Badoux 2011).

A more sophisticated version of the hydrothermal carbonization process of cellulose is given for chemists in Figure 8.

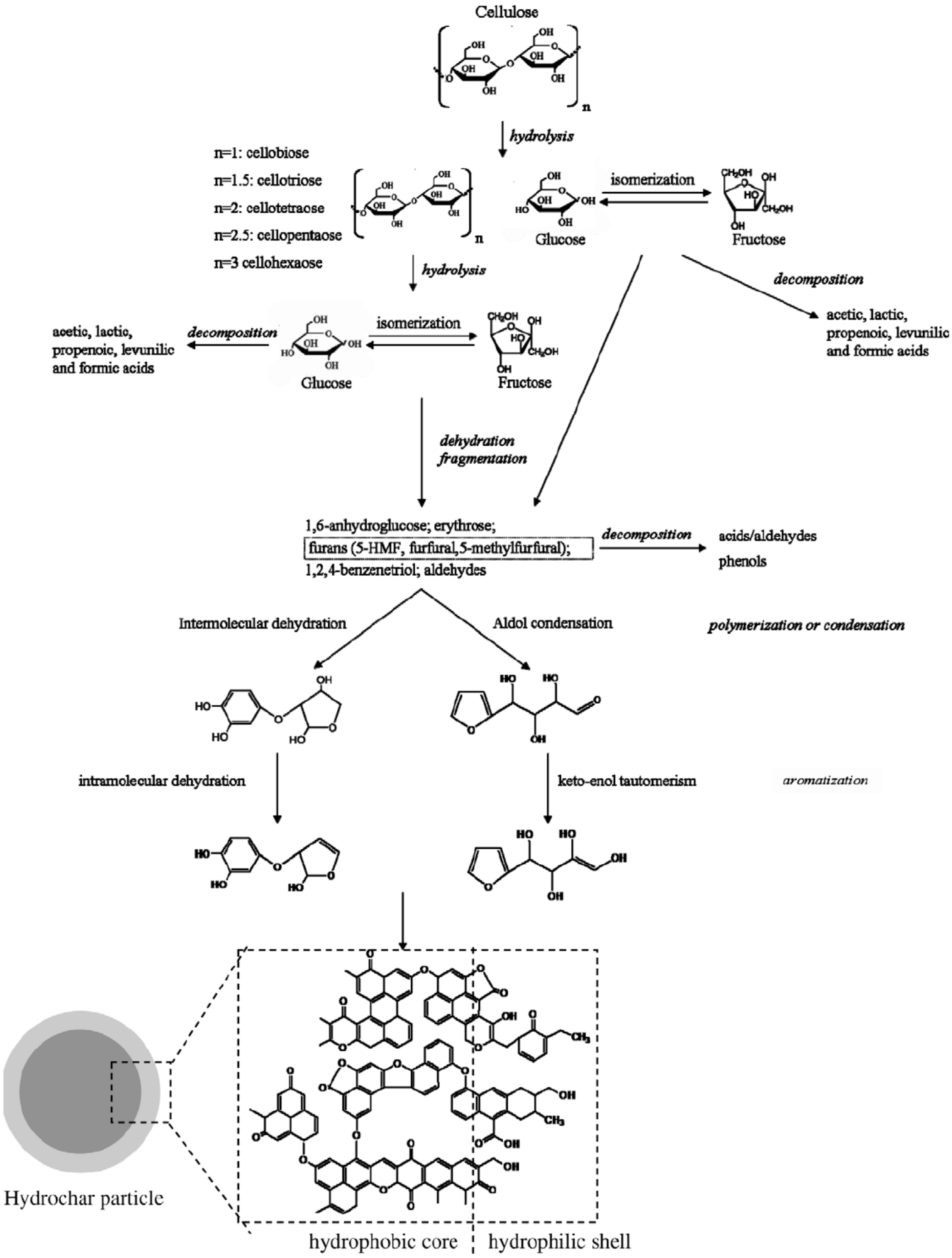


Figure 8 Mechanism of formation of biocoal particles from cellulose (Source: Sevilla 2009).

As usually for chemical processes of organic matter, several side reactions take place during hydrothermal carbonization as shown in Figure 9. By optimizing the reaction parameters (pressure, temperature, time, catalyst) the desired reaction pathway can be favored. However, it has to be mentioned that not all carbon of the biomass is converted to biocoal, but that the process water is saturated with organic compounds like phenols and organic acids and part of the carbon is lost as carbon dioxide.

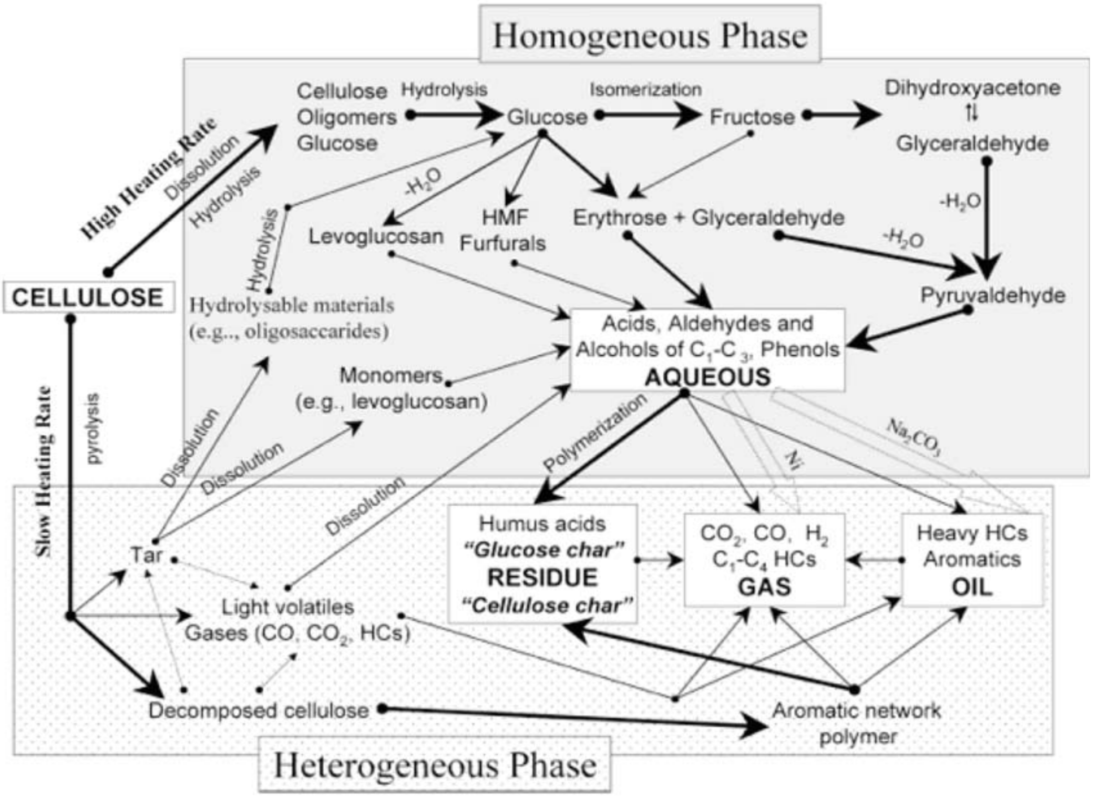


Figure 9. Reaction schemes of cellulose (Source: Fang 2004).

Figure 10 shows data of a typical hydrothermal carbonization experiment of organic matter performed by the research team headed by Prof. Ramke. In shown case a mixture of maize silage and sugar beet chips where used as input material. The hydrothermal carbonization process is usually characterized by following phases.

1. Heating of input material

   This is the phase during which external heating is necessary to start the process.

2. Reaction phase

   During this phase the hydrothermal reaction takes place. In order to keep the temperature constant cooling or additional heating is necessary. In principal, the hydrothermal carbonization of biomass is an exothermic process. However, due to the fact that no agitation of the material within the reactor has been possible, additional heating had to be done from time to time. Keeping the temperature of the substrate at a constant level has been one of the major challenges of these experiments.

3. Cooling Phase

   Time after finalization of reaction till cooling down for further processing (depressurizing, filtering,…).

4. Depressuration

   Final process step before further handling of the final products (mainly biocoal and process water).

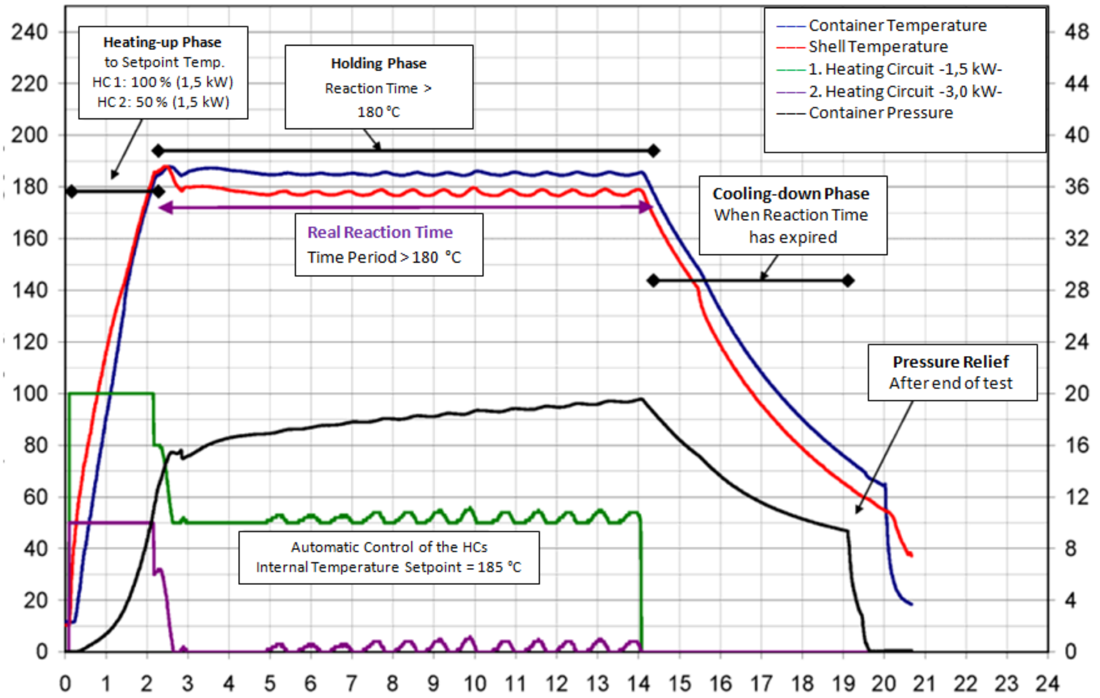


Figure 10. Typical characteristics of HTC process parameters (Source: Ramke 2010).

3.4.3 HTC-Products from Different Feedstock

Hydrothermal carbonization of biomass leads to three products: HTC-coal, HTC-water and HTC-gases. The carbon of the feedstock is usually distributed between the three fractions in following way:

Table 2. HTC-product distribution (Source: Libra 2011)

HTC-coal (wt%)	HTC-water (wt%)	HTC-gases (wt%) (carbon dioxide, methane)
50-80 wt%	5-20 wt% (dissolved in process water)	2 – 5 wt%

<ins>HTC-coal</ins>

Figure 11 demonstrates the hydrothermal carbonization of several samples used by Prof. Ramke's team. These range from hard, lignocellulosic biomass, over soft biomass to leftovers and sludge. Interesting is that all vectors from the educt to the final biocoal are quite parallel to each other, suggesting a similar conversion pathway. The lengths of the vectors give a good indication of the necessary reaction time. Although, it should be kept in mind that other parameters especially the initial temperature seem to have a significant influence on the process time also (Ramke 2010). This is especially valid in cases where the cellulose is "wrapped" in other materials like lignocelluloses (Dinjus 2011).

However, Figure 11 shows quite impressively that the possible feedstock variation for the hydrothermal carbonization process is comprehensive, leading to a product which seems to be comparable with brown coal. This is even more fascinating with respect to the fact, that the feedstock can be used without any drying step.

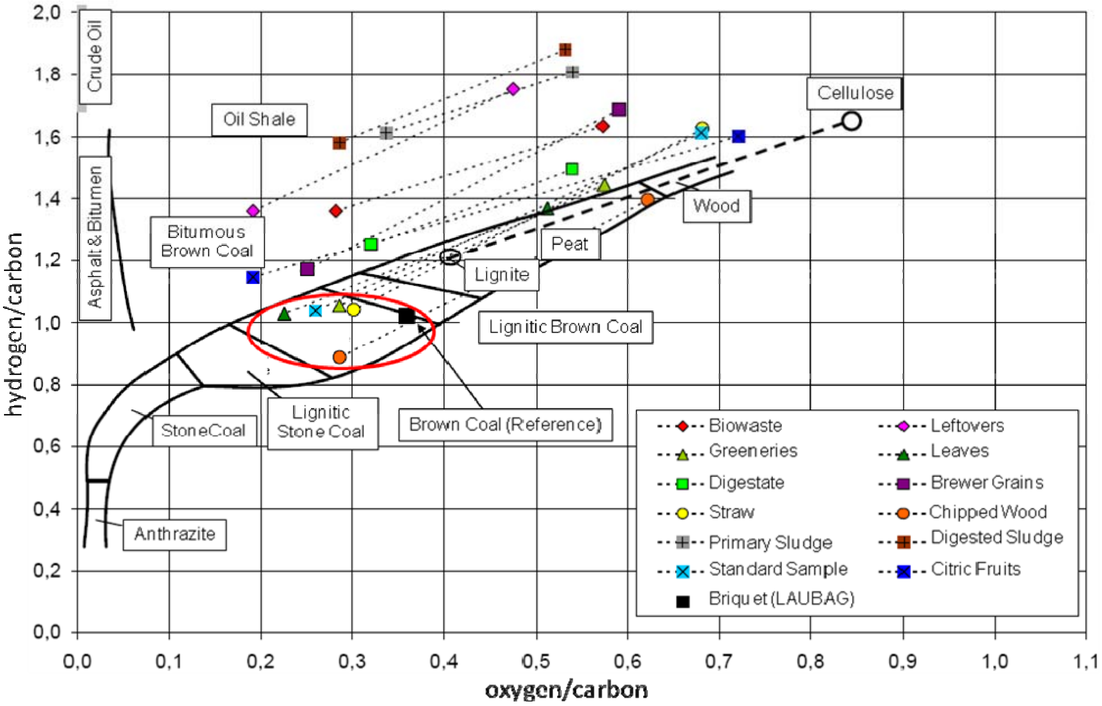


Figure 11. Hydrothermal carbonization of different feedstock (Source: Ramke 2010).

<u>HTC-water</u>

Hydrothermal carbonization uses water as process media. In addition, water is “produced” by dehydration reactions of the biomass. Depending on the water content of the feedstock, HTC-process water is can be up to 10 t per t HTC-coal (Vorlop 2009).

HTC-process water from organic waste has usually a pH- value between 3.7 and 5.2. Some of the inorganic compounds are in solution but the main dissolved contents are of organic origin.

The chemical oxygen demand (COD) is in the range of 14,000 to 70,000 mg per liter, while the total organic carbon (TOC) is between 9,000 and 28,000 mg per liter. However, the corresponding COD/TOC ratios are about 2.5 mg/mg indicating a relatively high oxygen content of the dissolved organic molecules. Compare with the COD values, the biochemical oxygen demand (BSB_5) has been found to be low, assuming a good biodegradability of the organic fraction.

Nutrients and metals do not seem to be present in HTC-water (Ramke 2010).

<u>HTC-Gases</u>

Only 2-5 wt% of the organic carbon is converted to gas. The main fraction is carbon dioxide (> 90%) and methane (< 5%).

3.4.4 Alternative Utilization of the Hydrothermal Carbonization Process

In the last view chapters it has been shown, that nearly every sort of biomass can be used to produce a brown coal like product. But the production of bio coal for heating purposes is only the simplest application. The charm of the hydrothermal carbonization process is that it has not only the ability to act as new biomass conversion process to gain energy or as new waste treatment process, but to represent a relatively easy, green and scalable process to produce products applicable in relevant fields of modern materials device manufacturing and the chemical industry (Titirici 2010, Chen 2012). These applications range from use of HTC products as soil conditioner, water purification material (Kumar 2011, Sun 2011), catalysts or electrode material in energy storage devices. Even as possible route for CO2 sequestration, HTC products have been suggested (Titirici 2007, Sevilla 2011).

4 Set Up of Case Study

4.1 Technical Assumptions

In the previous chapters an introduction into the hydrothermal carbonization process and its possible applications were given. Although the achievable properties of the HTC products are very appealing, it seems that the first marketable applications will be the use of the HTC process for the treatment of biowaste and sludge. One of the most common disposal routes for municipal, organic waste is composting. Thus, it is the intention of this thesis to analyze the technical and financial feasibility of implementing the HTC process into an existing composting facility.

The case study is based on a real composting facility. However, the presented case only reflects a feedstock composition which could be handled by the owner of the composting facility, but does not reflect the actual situation. Another reason this case model has been chosen is that the owner of the composting facility also runs a small local district heating grid fueled with wood chips, giving the opportunity to co-fire the produced HTC-coal.

The yearly processing capacity of fresh biomass was set to 10,000 tons for two reasons. First it is the convenient limit of the possible amount of organic waste which could be secured on a long term basis from the considered region. Second, during the first contacts with potential HTC process plant vendors, it seemed that a plant size of 10,000 to/year is the lower limit to be financially feasible.
As input material for the HTC process following organic waste has been assumed:

Table 3. Feedstock composition case study.

Feedstock[2]		
Horse dung[3]	5000	t/a
Bio-waste container material[4]	3000	t/a
Wooden material[5]	1000	t/a
Grass & Foliage	1000	t/a

Using these input data a questionnaire has been developed and sent to potential HTC plant vendors (see ANNEX 1). With this tool following main issues shall have been inquired:

- General process parameters
- Energy consumption and utilities
- Product properties (HTC-coal and process water)
- Capital Expenditures (CAPEX)
- Operational Expenditures (OPEX)

Based on the provided data from the vendors a simplified block diagram of the main process steps has been developed in order to identify the main investment items ANNEX 2.

It has been assumed that following existing infrastructure of the compost plant will be used and are not part of the investment costs:

- weigh-bridge
- intermediate storage space
- sufficient paved surface
- electrical power
- fresh water supply
- sewer junction
- office space
- connection to district heating grid

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[2] Composition assumed for case study only

[3] 50% straw litter, 50% sawdust litter

[4] Summer (90% garden waste, 10% leftovers), Winter (10% garden waste, 90% leftovers)

[5] Greeneries, stools, waste wood

The work flow is assumed to be following:

1. Delivery, weighting and acceptance of feedstock material.
2. Intermediate storage.
3. If necessary, shredding of feedstock with external, mobile shredder.
4. Transport of feedstock to mixing tank via belt conveyer.
5. Mixing of different feedstock in mixing tank, adding necessary fresh/process water, adding of organic acids for optimal pH value.
6. Transport of mixed feedstock to HTC-reactor via screw conveyer.
7. Heating of HTC-Reactor via steam (steam is provided by wood chip fired steam generator).
8. Temperature control by cooling water (heat exchanger with district heating grid); air-cooler for emergency cases.
9. Decanter (HTC-coal 35% TS).
10. Coal dryer (HTC-coal 90% TS).
11. Process water tank. Process water not recycled to HTC-Process is sent to duct work.
12. Big pack filling station for HTC-coal for external sale.
13. Alternative:
    - Transport of big packs to nearby district heating station
    - Firing of HTC-coal in wood chip furnace for district heating net run by the owner of the local district heating grid.

Based on the above given feedstock the expected product yield has been estimated together with experts form Smart Carbon. Thus, following product streams have been assumed for the financial model (see “Input Data” presented in ANNEX 2):

Table 4. Product yield case study.

HTC-coal (90% TS)			**Heat export (district heating)**	**HTC-water**
2300 t/a	3550 m³/a	15,7 MJ/kg (LHV) [6]	3600 MWh/a	7900 t/a

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[6] Lower heating value (LHV) is dominated by HTC-coal from horse dung. Heating value (LHV) of horse dung has been set more conservative according to the experience of Smart Carbon compared to published values (Patscheider 2011).

4.2 Financial Assumptions

As price basis, values from 2012 have been used. The project life time has been set to 20 years, starting operation in January 2013 after a construction period of 6 month.

The input parameters used for the financial model are given in the worksheet “Input Data” presented in ANNEX 2. Following assumptions are underlying the financial projections of the presented model.

As already described in the methodology chapter, three different cases have been set up: “normal, middle-of-the road”, “best case”, “worst case”,

4.2.1 Scenario 1 “middle-of-the-road”

The assumptions made for this case are the best guess currently possible and should be the most realistic ones also. It is the basis for the other two cases also.

4.2.1.1 Total Investment Costs

The total investment costs were based on the technical assumptions and the feedback from our colleagues of the “HTC-Netzwerk” in Germany, sponsored by the Federal Ministry of Economics and Technology in Germany. The capital expenditures (CAPEX) were roughly estimated, taking into account the costs for the adaptation of the compost plant also. In addition to the CAPEX, 10% of the CAPEX were added as contingencies summing up to the total investment costs. These estimated total investment costs are about 20% to 80% above the ones published but seems more realistic for (Erlach 2011, Badoux 2011, TerraNova Energy 2011, Freitag 2010).

For the influence of a possible grant on the CAPEX, it has been assumed that 25% of the CAPEX (without contingencies) are provided as non-refundable public grant.

4.2.1.2 Operational Expenditure

Operational expenditure (OPEX) were based on vendor information and own assumptions based on the actual OPEX of the compost plant.

For the personal costs, two full time operators and 208 hours per year for management activities have been calculated.

Utility consumptions have been calculated, based on the estimates from the vendors.

The production of steam for heating up the HTC-reactor has been assumed to be provided by a wood chips boiler, as the owner of the compost plant is producing wood chips himself and no access to a nearby natural gas supply is available. Thus, a lower heating value of 3,3 kWh/kg and 100 €/to internal costs have been taken into account for the wood chips.

Other utilities like electricity, fresh & waste water and chemicals have been taken into account also.

Furthermore, additional costs for external feedstock preparation (e.g. shredder), maintenance, land lease and insurance have been added to the OPEX.

5 % of the above mentioned costs without land lease and insurance have been allowed for OPEX contingencies.

The overall OPEX as described above are about 13,9% of the total investment costs. This is in line with published data, which assumed OPEX of around 10% (Erlach 2011, Badoux 2011, TerraNova Energy 2011).

4.2.1.3 Inflation and escalation rates

For the inflation rate as well as the escalation rate for utilities and personal costs, the harmonized consumer price index as forecasted by Statistik Austria has been used (Austrian Economic Chambers 2011).

The discount factor has been set up assuming following points:

- 30 years euro SWAP rate: 3%
- Technology risk: 3,5%
- Feedstock risk: 2%

Thus, a discount factor of 8,5% has been applied .

4.2.1.4 Yield

The yield of HTC-coal given under “positions relevant to income account” in the work sheet “Input Data” of the financial model in ANNEX 2 has been assumed according to vendor information.

4.2.1.5 Sales Price Assumptions

For the base case, the price of the HTC-coal has been set to the current market value of HTC-coal estimated by HTC-plant vendors (Badoux 2011).
Excess heat from the HTC-process is suitable to be fed into and sold via the local district heating grid owned by the compost plant operator.

4.2.1.6 Working Capital

A 30 day average payment period of current liabilities as well as for the collection of account receivable has been assumed.

4.2.1.7 Depreciation

Depreciation addressed in the financial model follows the straight-line method according to the useful lifetime of the plant. The depreciation has been calculated on all fixed and capital assets. A life time of 20 years has been assumed for 70% and 10 years life time for 30% (e.g. pumps, heat exchangers,…) of the plant total investment costs. Thus, allowing 5% depreciation per annum for 70 % and 10% depreciation per annum for 30% of the total investment costs.

4.2.1.8 Funding

Funding is assumed to be spread between 25 % equity capital from investors and 75% bank long term debt. Bank debt is assumed till the end of the project life time of 20 years at 4% fixed interest rate starting repayment one year after start up. No short term debts are assumed.

4.2.1.9 Profit Distribution

The case study presented in this thesis is assumed to be operated by a special purpose vehicle (SPV). The profit distribution policy is structured so as to take the cumulated retained earnings and cash available for distribution into account. In addition, profit distribution starts after the first debt repayment. Dividends are distributed only under the following circumstances:

- The cash available for distribution is positive.
- The cumulated retained earnings for distribution are positive.
- The minimum DSCR is equal or greater 1.20x.
- Repayment of debt is done.
- Only 75% of the free cash after tax and financing are distributed.
- At the end of the project life time the remaining free cash after tax and financing is distributed.

4.2.2 Scenario 2 “best case”

As the realization of the project would be the first in Austria it has been assumed, that a non-repayable funding of 25% of the total investment costs (without contingencies) is possible. In addition, an optimistic HTC-coal price given by vendors of HTC-process plants and the possibility to sell CO2 certificates (currently 6 €/to CO2) have been taken into account.

All other parameters were chosen as in chapter 4.2.1 (Scenario 1 “middle-of-the-road”) and are given in work sheet “Input Data” of the financial model in ANNEX 3.

4.2.3 Scenario 3 “worst case”

The third case is based on the “middle of the road” scenario also. But HTC-coal prices were set to the ones comparable to the 2012 price for wood pellets DIN EN 14961-2 Class A1 (4,41 ct/kWh[7]) in Austria. For comparison, the HTC-coal price has been calculated based on it’s estimated lower heating value.

All input parameters are presented in work sheet “Input Data” of the financial model in ANNEX 4.

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[7] Pro Pellets Austria: Energieträger im Vergleich, Stand März 2012.

5 Results

5.1 Theoretical Background

Up to now, it has been shown by several studies that hydrothermal carbonization can convert nearly all organic biomass to a hydrophobic solid of reduced mass and increased fuel value, and process water. The feedstock can be used without any special pretreatment (e.g. drying) and so far no restrictions have been found regarding the composition of the organic matter. The processed product can be handled quite easily, having relatively homogeneous properties. Thus, it seems that by using hydrothermal carbonization, two major hurdles for the broad acceptance of biomass as sustainable fuel for large-scale biomass applications (IEA Bioenergy 2011), low homogeneity and the transportation of large amounts of feedstock (energy density!), can be handled. The two mentioned disadvantages can be overcome using hydrothermal carbonization by reducing volume, increasing energy density and equalizing energetic homogeneity.

5.1.1 Process Parameters

Systematic studies of organic waste performed by Ramke et al. (Ramke 2010) showed differences regarding the possible depth of carbonization of the different feedstock material. The differences originate mainly from following parameters:

- Inorganic contents
- Fraction of Lignocelluloses (“hard biomass”)
- Content on carbohydrates, fats and proteins

A high inorganic content in the feedstock (e.g. digested sludge) shows less intensification of the specific heating value in the HTC-coal.

High lignocellulosic fractions need higher process temperatures and times, but lead to a better “carbon yield” in the HTC-coal (less losses to water and gas fraction).

High contents of carbohydrates, fats and proteins lead to a HTC-coal more comparable to bituminous brown coal.

Figure 12 plots the carbonization products of different feedstock (Ramke 2010). It shows the increase of the specific heating value with regard to the intensification of the carbon content. Using this plot, Ramke et al. could group the produced HTC-coal into four different classes:

- perfect carbonization
- very good carbonization
- good carbonization
- poor carbonization

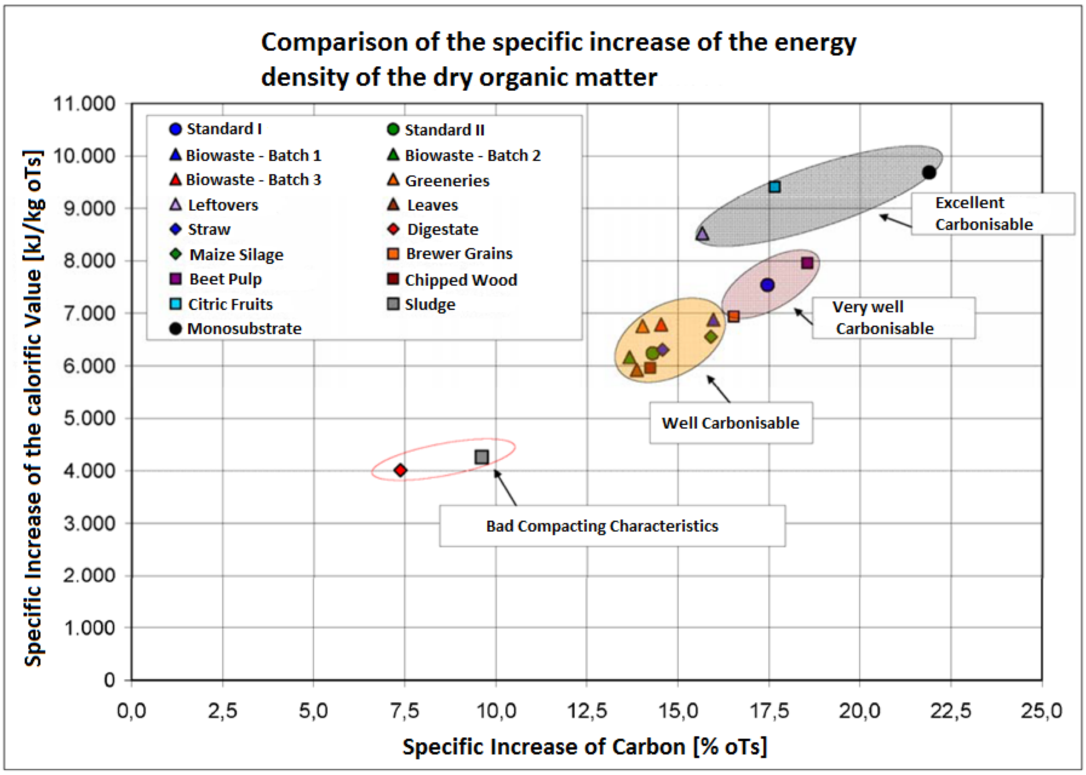

Figure 12. Increase of specific heating value depending on the intensification of the carbon content by hydrothermal carbonization (Source: Ramke 2010).

General observations made by Ramke at al. (Ramke 2010) regarding the process parameters are summarized on the following pages:

<u>Temperature</u>

It was been shown that the reaction temperature is the most critical process parameter for a successful carbonization. Specially biomass with a high content of lignocelluloses needs a reaction temperature above 200°C to gain good carbonization results.

Till the experiments from Ramke et al. the usual temperature published for the carbonization process of biomass was around 180°C. This worked out fine for biomass with a low content of lignocelluloses, but lead to nonsatisfying results with lignocellulosic material like straw, digestate and fresh compost. Using a higher temperature between 230°C to 235°C for 1.5 hours lead to the expected results.

Interestingly, by keeping the temperature afterwards between 175°C to 190°C, good HTC-coal qualities could be achieved. According accompanying research activities by Prof. Antonietti at the Max Planck Institute of Colloids and Interfaces in Golm, the coal-monomers generated during the first high-temperature phase of the carbonization process polymerize to HTC-coal during this second phase.

Another result of this systematic approach is that an increase in reaction temperature of 10°C equals approximately a doubling of the reaction time. This means that the same depth of carbonization can be achieved by either raising the reaction temperature by 10°C or doubling the reaction time.

However, the necessary reaction temperature strongly depends on the feedstock composition. Thus, optimization of the process parameters has to be done prior to a large scale application.

<u>pH-Value</u>

Hydrothermal carbonization works best in water with a pH-value between 5.0 and 5.5. Values below 4.5 lead to the formation of levulinic acid which is usually accompanied by formic acid. With regard to large scale applications of the hydrothermal carbonization, the formation of these two acids has to be kept in mind especially regarding industrial safety.

There are some indications that initial pH values above 7 result rather in a liquid than a solid product (Ando 2000, Hu 2008).

Depending on the different feedstock certain substances are used to control the pH - value (e.g. citric acid, sulfuric acid, acrylic acid, calcium carbonate, oxalic acid) (Hu 2008, Titirici 2007, Demir-Carkan 2009). Using organic acids has the advantage, that they are finally ”carbonized” also, while inorganic substances can increase the mineral content of the HTC-coal.

Catalyst

Several studies show that the addition of catalysts influences the carbonization reaction (Ramke 2010, Titirici 2010, Lynam 2011, Chen 2012). As usual for polymerization processes, peroxides and metal ions also favor polymerization reactions leading to lower carbonization times. This seems to be an interesting point for possible applications for continuously operated HTC-reactor types. The correct time for the injection of the catalyst as well as the optimized dose will be one of the key issues for optimizing a continuous HTC-process.

Recirculation of process water

Recirculation of process water has a positive effect on the carbonization of biomass. It is assumed that not polymerized carbon of the recycled process water acts as initiator for the polymerization of the fresh feedstock coal-monomers. By recycling process water, the aqueous phase is saturated with carbon leading to a reduction of carbon losses from the feedstock with respect to the final HTC-coal. But it has to be kept in mind, that the inorganic fraction of the HTC-coal will be increased too.

First experiments with surplus carbon-rich process water showed good anaerobic as well as aerobic reactivity.

5.1.2 HTC-coal as combustible

As already mentioned before, hydrothermal carbonization of biomass leads to a hydrophobic solid of reduced mass and increased fuel value. The heating value is comparable to brown coal.

Figure 13 shows the dependency of the (higher) heating value of the produced HTC-coal on its carbon content. It was found that the contents of carbon (C), hydrogen (H), nitrogen (N) and oxygen (O) have by far the largest influence on the heating value of the HTC-coal. Thus, the theoretical heating value can be estimated quite well by using the standard formulas from Dulong, Boie and Michel (Ramke 2010).

As shown in Table 5, for all organic feedstock an increase in the higher heating value could be achieved by using hydrothermal carbonization.

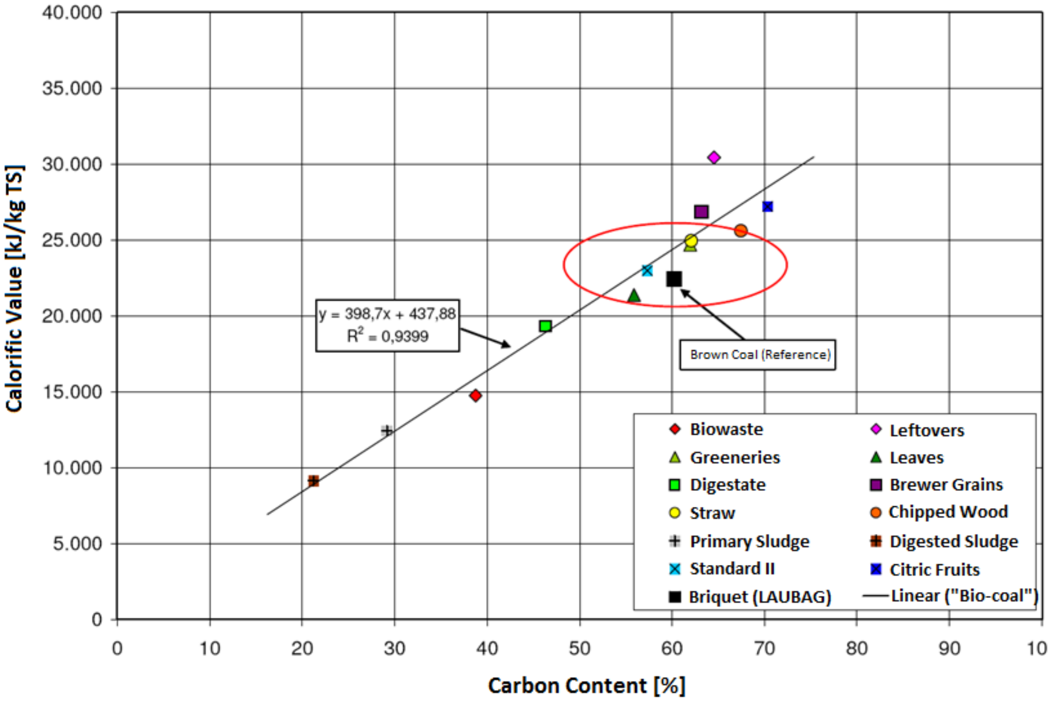

Figure 13. Heating value (higher) of HTC-coal depending on the carbon content of the product (Source: Ramke 2010).

Table 5. Higher heating values of feedstock and corresponding HTC-coal.

		higher heating value			
		Feedstock	HTC-Coal	difference	
		MJ/kg	MJ/kg	MJ/kg	%
Ramke (2010)	Leftovers	20.2	29.2	9.1	44.9%
	Citric fruits	16.8	25.8	9.0	53.7%
	Bio waste	15.1	17.0	1.8	12.2%
	Digestate	17.1	19.3	2.2	12.8%
	Greeneries	18.2	21.2	3.0	16.4%
	Leaves	19.7	24.9	5.2	26.4%
	Foliage	17.4	19.7	2.3	13.0%
	Maize silage + sugar beet pulp	16.9	22.0	5.1	30.4%
	Sugar beet pulp + straw + digestate	16.9	20.0	3.1	18.3%
	Straw	18.6	23.4	4.8	26.1%
	Brewer grains	20.5	26.8	6.3	30.6%
	Sugar beet pulp	17.2	23.6	6.4	36.9%
	Sludge	13.9	14.2	0.3	2.2%
(Lu 2011)	Japanese municipal solid waste	16.1	16.4	0.3	1.9%
	India municipal solid waste	15.7	17.9	2.2	14.0%
	Chinese municipal solid waste	17,6	24,9	7,3	41,5%

Quite interesting are the results from Lu L. et al. (Lu 2011) who investigated the possibility to treat municipal solid waste. Due to the large organic content of solid wastes in Japan, India and China, even these feedstock showed an increase of the higher heating value. The most outstanding result of this study is the increase of the energy content per volume of the treated feedstock as shown in Table 6 below.

Table 6. Higher heating values of HTC-coal from municipal solid waste (Source: Lu 2011).

	Higher Heating Value								
	Feedstock		HTC-coal		differences		increase		Org. content
	MJ/kg	MJ/m^3	MJ/kg	MJ/m^3	MJ/kg	MJ/m^3	MJ/kg	MJ/m^3	wt. %
Japanese MSW	16.1	1771	16.4	11316	0.3	9545	1.9%	539%	87.8
India MSW	15.7	1884	17.9	12888	2.2	11004	14.0%	584%	68.0
Chinese MSW	17.6	1936	24.9	17430	7.3	15494	41.5%	800%	80.7

The increase in energy content per volume (MJ/m^3) is about 6.39 to 9.00 times compared to an increase in energy content per weight (MJ/kg) of 1.01 to 1.41 times. This shows impressively that while combustion behavior of municipal solid waste is usually mainly controlled by the substances in majority in weight, the HTC-coals gained from this feedstock show a different behavior. The combustion behavior of these MSW-HTC-coals is mainly dominated by the organic fraction of the feedstock.

For the application of HTC-coal as combustible other parameters like ash fraction, ash melting behavior etc. have to be taken into account in addition to their heating value. As the commercial adaptation of the HTC-process is just starting, there is restricted information available on the market regarding combustion properties of “commercial HTC-coal”. In addition, it has to be mentioned that HTC-coal has not been accepted as standard fuel on the market till now and additional research and development is necessary to evaluate the applicability of HTC-coal in currently available firing systems.

The ash content mainly depends on the inorganic content in the feedstock. As organic feedstock is usually low in inorganic substances, HTC-coal has low ash content. In addition, it seems that the ash melting temperature is comparable to the one of brown coal. At least this is valid for HTC-coal derived from wood chips or spent grains. The application of HTC-coal as standard fuel for biomass-firing or co-firing has to be evaluated for each feedstock separately, especially in large scale applications. Table 7 gives an overview on currently available “commercial” HTC-coal.

Table 7. Comparison of ash content and melting behavior.

		brown coal	wood chips (SunCoal)[8]	spent grains (AVA CO2) [9]
lower heating value	MJ/kg	21.6	20.0	25.0
ash content	wt %	7.2	1.2	n.a.
ash melting temperature	°C	>1100	~1200	~1400

5.1.3 Carbon efficiency[10]

By using the traditional processes for the conversion or management of organic waste and biomass, large parts of the original feedstock are released to the atmosphere as carbon dioxide and/or methane. Thus, these processes can be seen as “climate neutral”, if at all, but do not have the ability to act as “carbon sink”.

Carbon dioxide is bound by photosynthesis in biomass consisting of e.g. cellulose, starch or sugar. These molecules building up the organic substance can be seen as energy storage devices, which provide this energy by e.g. combustion. During alcoholic fermentation of sugar around 15% of the stored chemical energy is lost and roughly 44% of the carbon is lost as carbon dioxide leading to a carbon efficiency (CE) of CE=0.66. Using anaerobic fermentation 18% of the stored energy is lost at best (theoretical value) and approximately 50% of the carbon is converted to carbon dioxide.

As shown in Figure 14 below, by using hydrothermal carbonization, nearly all carbon of the organic feedstock can be fixed in the respective products (coal and water), restoring about 66% of the original chemical energy. Thus, at least for those cases, where organic waste or biomass cannot be combusted directly (without additional energy input e.g. drying), or when alcoholic and anaerobic fermentation is not feasible due to the feedstock composition, hydrothermal carbonization offers a reasonable alternative.

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[8] SunCoal Industries GmbH: Die Biokohle-Produkte der CarboREN-Technologie. 2011.

[9] AVA-CO2 Schweiz AG: Factsheet AVA cleancoal®. 2011

[10] Carbon Efficiency (CE) is defined as the realtive amount of carbon from the starting product bound in the final product. This is analogous to the group efficiency in green chemistry. (Titirici 2007).

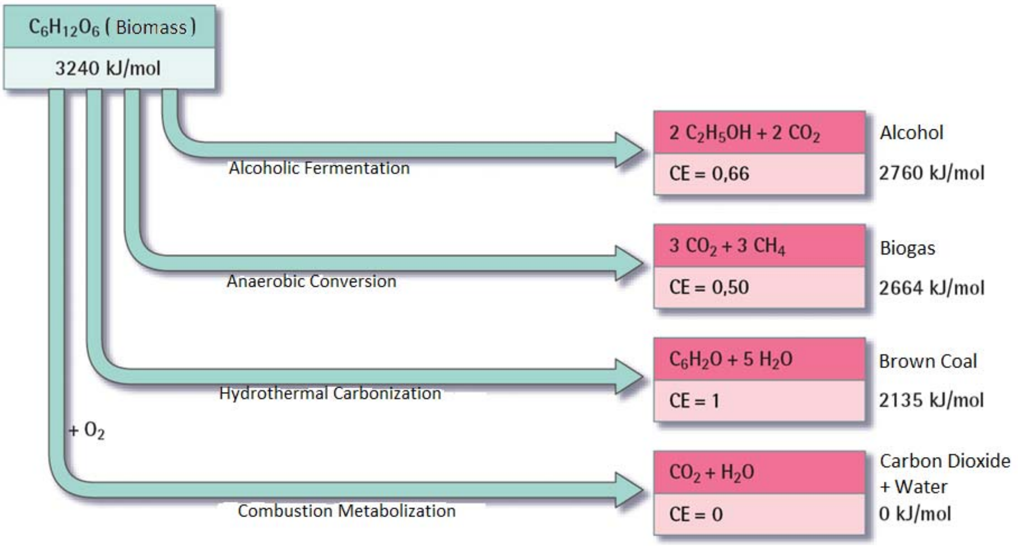

Figure 14 Preservation of combustion energy and carbon efficiency (CE) of different biomass conversion processes (Source: Titirici 2010, Röthlein 2006).

Another aspect of the carbon efficiency of the HTC-process is its comparison with natural decomposition process of biomass. As soon as biomass (and other organic matter) starts to decompose, the organic components are released in large quantities of carbon dioxide and methane to the atmosphere.

As shown in

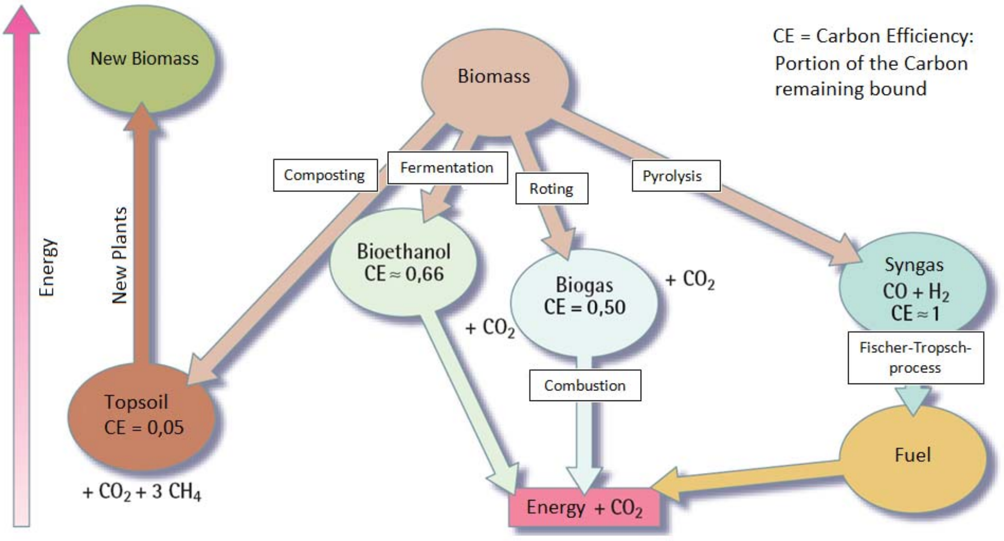

Figure 15 especially composting releases almost all organic matter as climate-affecting gases (methane and carbon dioxide). In contrast, the products derived from the HTC-process (coal and water) sum up to a carbon efficiency of one, which means that hardly any carbon is released as carbon dioxide (or methane).

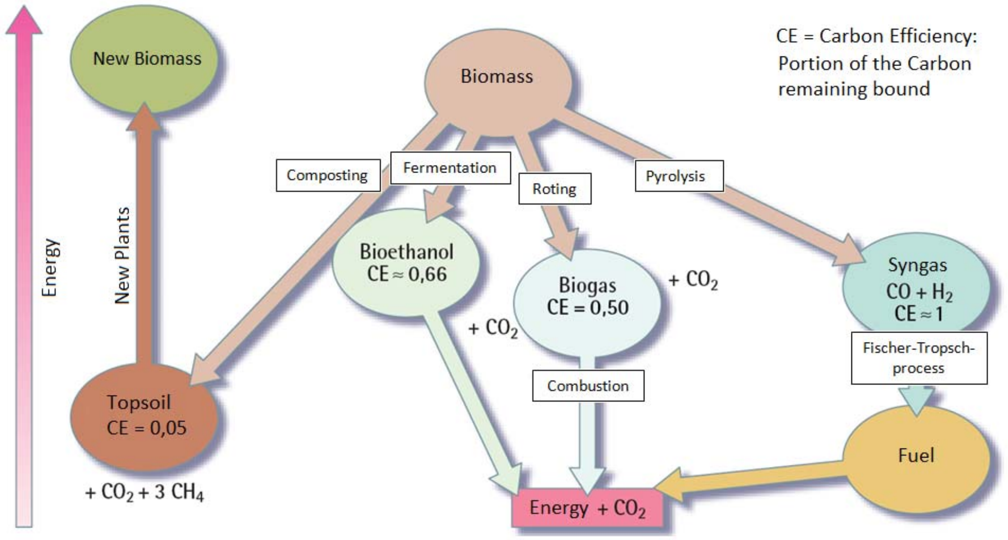

Figure 15 Current biomass management schemes (Source: Röthlein 2006).

Based on the HTC-process an alternative biomass management can be provided leading at least to the same final products, but with better carbon efficiency. When used as topsoil the HTC-process acts as possible route for the sequestration of carbon dioxide (Titirici 2007, Sevilla 2011).

5.1.4 HTC-coal as soil conditioner

As already mentioned in the introduction section, the erosion of fertile soil is a severe problem arising right after peak oil. That this issue is not only a problem of underdeveloped arid countries is shown by the fact that even the European Commission defined certain milestones to address the problem of soil erosion in Europe (European Commission 2011). The application of bio-char produced by torrefaction or pyrolysis for the remediation, revegetation and restoration of depleted soils started to gain momentum recently (Rillig 2010, Lehmann 2011, Beesley 2011). The international biochar initiative is currently preparing Guidelines for Specifications of Biochars (The International Biochar Initiative 2011).

The great advantage of hydrothermal carbonization is the possibility to process the organic material along a defined pathway in the Van Krevelen plot (Behrendt 2006). By stopping the process at an early stage a nutritious rich material can be obtained, which is spread to be similar to terra preta. This black terra preta is associated with long-enduring, Indian village sites, and is filled with ceramics, animal and fish bones, and other cultural debris. Terra preta is much more fertile than the surrounding highly weathered reddish soil and it has generally sustained its fertility to the present despite the tropical climate and despite frequent or periodic cultivation.

For what is true, is the assumption that due to the fact that HTC-coal is rich in functional groups and can be derived from the process in a “wet” condition, it shall give the possibility for the settling of soil bacteria more easily compared to the bio-char derived by torrefaction or pyrolysis.

However, additional research projects and field test have to be performed in order to verify the long term effects of the HTC-coal on the soil (Lehmann 2011).

5.1.5 Other applications of the HTC-process

Although the introduction of hydrothermal carbonization as pretreatment process for large-scale biomass applications seems to be the first marketable possibility for this technology, there are several other options the products of the HTC-process could be used for. A hint of these possibilities were given by Maria-Magdalena Titirici and Markus Antonietti in their 2010 tutorial review (Titirici 2010).

They showed that hydrothermal carbonization could be used as environmentally friendly process for the production of functional, nanostructured materials from cheap natural precursors. Using this approach Titirici et al. synthesized metal oxide nanostructures for electrical applications, catalysts with Nobel metal salts, as well as electrode material for lithium ion batteries and carbon fuel cells.

Chen et al. used hydrothermal carbonization for the synthesis of carbon microspheres (CMSs), which are believed to have great potential application in catalyst supports and adsorbents, as well as electrodes or templates for fabricating core-shell or hollow structures. They showed that carbon microspheres obtained from alginate by hydrothermal carbonization may have great potential for the application in biochemistry, drug delivery and catalyst supports (Chen 2012).

Another promising application of HTC-coal is for water purification issues. Due to its high adsorption capability Kumar at al showed, that HTC-coal produced from switchgrass could serve as environmentally benign, carbon neutral and efficient low cost material for the removal of radioactive substances like uranium (VI).

Heilmann S. et al. demonstrated in his series “Hydrothermal Carbonization of microalgae” that fatty acids, chars and nutrient-rich aqueous phases can be isolated from HTC-coal. Using the hydrothermal process algal oil products could be obtained in a very simple and energy efficient way. In addition, the process water could be used as legal nutrient solution and the HTC-coal for possible other applications mentioned above (Heilmann 2010, Heilmann 2011). An overview of this concept is given in Figure 16.

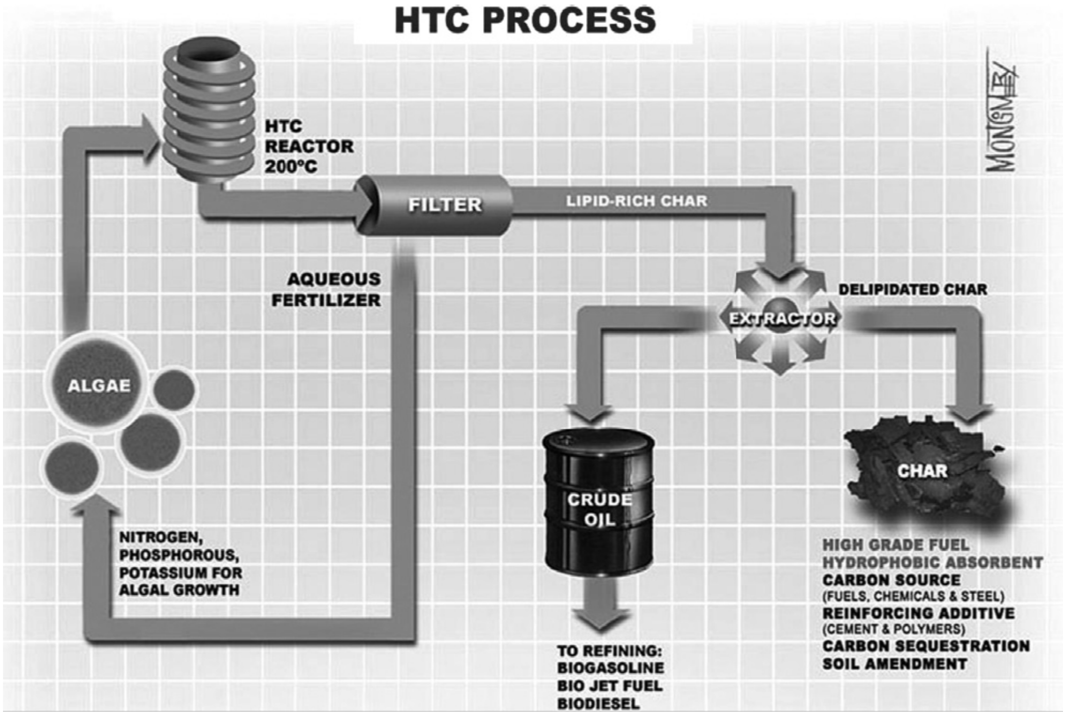

Figure 16. Schematic diagram for the application of the HTC-process for the algal oil industry (Heilmann 2011).

Lyman et al. discovered that even from HTC-process water high-value products can be gained (Lynam 2011). They showed that 5-hydroxy-methyl furfural (5-HMF) can be precipitated in significant quantities from the aqueous product stream. HMF itself is an interesting raw material due to its high reactivity and the polyfunctionality; it is simultaneously a primary aromatic alcohol, an aromatic aldehyde and a furan ring system. Derivatives of HMF have already been utilized in agrochemistry as fungicides, in galvanochemistry as corrosion inhibitors, in cosmetic industry and as flavor agents. It is also a good starting material for the synthesis of precursors of various pharmaceuticals, thermo-resistant polymers and complex macrocycles. Up to now the only major disadvantage of HMF are the high production costs.

These possible applications shall demonstrate that the HTC-process is not only a possible route for biowaste treatment, but has the potential to be applied for the production of high-valued products also.

5.2 Feedback from the HTC-market

In addition to the research of the scientific background of the HTC process, suppliers of HTC process plants have been contacted to get an impression on the current marketability of this biomass conversion technology. For this purpose a standardized questionnaire has been developed and sent to potential suppliers (see ANNEX 1). The questionnaire has been kept in German as all companies are currently located in Germany or Switzerland. Over all, ten companies were contacted in the first and second quarter of 2011. Seven out of ten responded to the inquiry, but none of them returned the completed questionnaires. The reason for that was that at this time, only three companies had already a scale up of their lab HTC-reactor (TerraNova, Sun Coal, AVA CO2).

In order to get a better insight into the actual market activities, ILF joined the “HTC-Netzwerk” in Germany, sponsored by the Federal Ministry of Economics and Technology in Germany. This network coordinates different small and medium enterprises in their effort to understand and enhance the hydrothermal carbonization process (HTC). The main goal of the HTC-Netzwerk is the development of a marketable HTC-process with high feedstock flexibility.

Thus, much information given in this chapter is based on direct communication of the author with the different members of the HTC-Netzwerk. One of the members is Smart Carbon, who developed the first 3,5 m^3 multi-feedstock reactor. This reactor type is currently implemented in a farming complex and shall process horse dung in the first trail runs.

Generally, there are currently two main philosophies regarding the design of the HTC-reactor. From the heat recovery management point of view a continuously operating HTC-reactor would be favorable (Stemann 2011). But one of the largest hurdles beside the optimized heat management itself, are the relatively long carbonization times needed. Thus, most vendors currently offer batch or semi-batch processes.

5.3 Case Study

5.3.1 Technical Feasibility

The case model presented in this study is based on a real compost plant. The proposed feedstock can be theoretically secured within the nearby region. Based on the theoretical background and discussions with several suppliers, carbonization behavior of the assumed feedstock mix should be quite good. In addition to the studies from Ramke at al. (Ramke 2010) regarding the carbonization of leftovers and grass/foliage, several suppliers already successfully performed carbonization tests of horse dung (Patscheider 2011).

From the technical point of view, it is feasible to implement the HTC-process into a compost plant, although, the exact process parameter have to be optimized with regard to seasonal variations of the feedstock. The existing infrastructures as well as the pretreatment processes of the feedstock like shredding and rejection of unwanted material (stones, iron, plastics…) are similar to the ones used for the processing of compost. The great advantages of the HTC-process compared to the compost process are:

- Less processing time leading to a higher throughput rate of organic waste at the compost site.
- Assured disinfection of the organic waste.
- No emission of climate relevant gases.
- Less product volume to be handled (HTC-coal).

However, there are still several technical issues that have be solved:

- Large amounts of process water.
- Proof of usability of the HTC-Coal as fuel for pellet furnaces.
- Optimized design for energetic efficient operation. (Stemann 2011, Funke 2011).
- Optimization of HTC-process parameters for described feedstock.
- Effect on HTC-coal properties of seasonal variations of feedstock.

5.3.2 Financial Feasibility

Most vendors claim that the minimum size of HTC-process plants to be financial feasible is 10,000 to/a biomass with about 35% dry matter. Up to date, no HTC plant of this size is in operation worldwide. In order to get realistic values, the presented case model is based on an existing and operating compost plant. The basic assumptions regarding CAPEX and OPEX are quite conservative compared to the data published by several vendors (see ANNEX 2, Badoux 2011, TerraNova Energy 2011, Freitag 2010).

Based on the given project data following finical results were derived for the three different cases.

5.3.2.1 Scenario 1 “middle-of-the-road”

As described in chapter 4.2.1, this case is the best guess for the data currently available on the market. OPEX and remuneration for feedstock acceptance are real 2012 prices form the compost market. The possible revenues for HTC-coal can only be estimated as there is currently no market for this fuel. In addition only revenues from selling of excess heat to the local district heating grid were assumed.

Possible revenues from selling of CO2 certificates, HTC-process water as fertilizer or HTC-humus were not considered, as the possible market for these revenues seems to be not feasible during the first stage of the market entry of the HTC technology.

However, based on several discussions with vendors and compost plant operators, colleagues from the HTC-Netzwerk and own experiences regarding plant engineering and construction, the author of this thesis is convinced that the assumed prices are the most realistic ones.

For scenario 1 following parameters were derived after taxes based on capital (equity + debt):

Table 8. Financial Output Parameters scenario 1 (middle-of-the-road).

Financial Output Parameters	**Scenario 1**
IRR	8.63 %
NPV	27 kEUR
Pay back period in years	20 years
Average DSCR	1.58x
Minimum DSCR	1.22x
Break Even HTC-Coal Price	238.64 EUR

The most realistic scenario estimates a positive net present value with a reasonable internal rate of return. The pay back period is similar to the life time of the project. The break even point analysis results in a HTC-Coal price nearby the price of 240€/to as proposed by several HTC-plant vendors.

Thus, it is no surprise that the success of the project is quite sensible to changes in several parameters. Changes of the IRR with respect to variations of the assumed parameters are given in Figure 17.

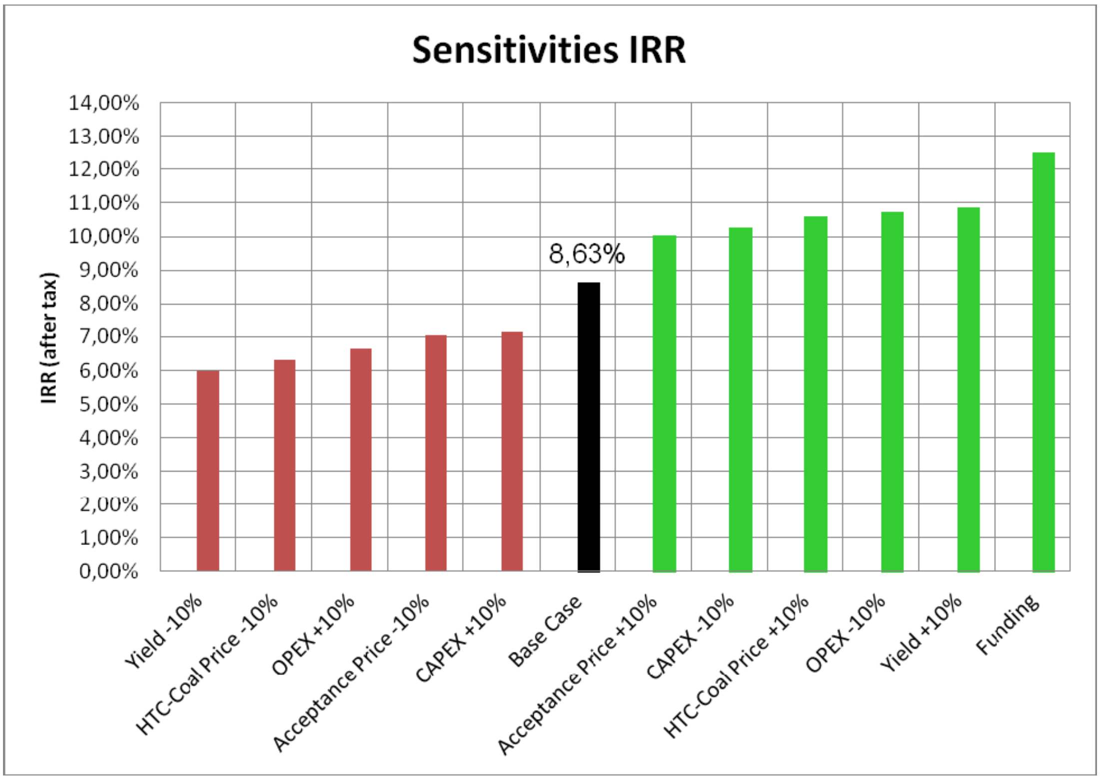

Figure 17. IRR sensitivities of scenario 1.

The largest positive change of the IRR would be the possibility of a non-refundable funding of 25% of the total investment cost (without contingenies). The largest negative effect has a reduction of the expected yield.

The elasticity factors given in Figure 18 describe how the IRR is influenced by chances in different assumptions. Values above “1” indicate that the IRR chances overproportional with regard to changes of the respective parameter. Negative values indicate that the IRR changes antiproportional with respect to the changes of the respective parameter (e.g. lower CAPEX higher IRR). As it can be seen in Figure 18, the highest impacts on IRR have changes in yield and HTC-Coal price. Both lead to a direct overproportional change of the IRR.

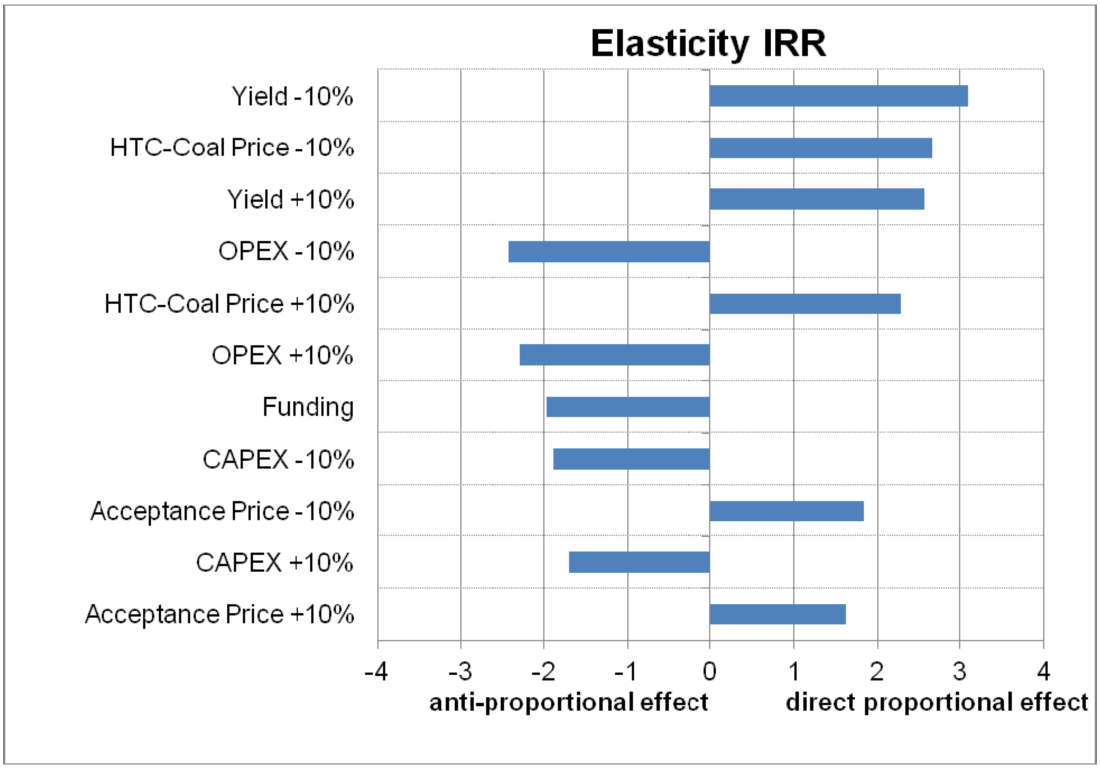

Figure 18. Elasticity values for different sensitivities for scenario 1.

In order not to be misleaded by the IRR a similar sensitivity analysis of the NPV has been made. Figure 19 presents the impact of changes of different assumptions on the NPV. It shows clearly that as the HTC-Coal price of the presented scenario is quite near the break even point, all changes which lead to a reduction of the NPV lead to a financially not feasible project (negative NPV!), although the corresponding IRR would be still acceptable.

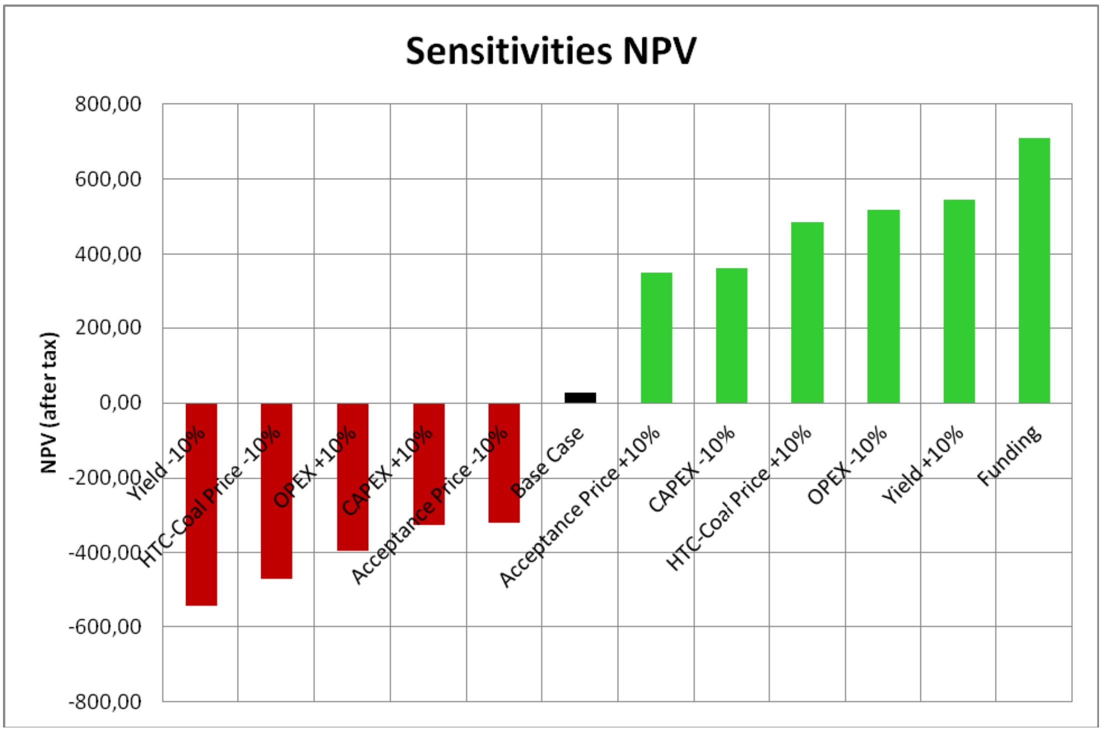

Figure 19. NPV sensitivities of scenario 1.

Detailed information of the financial model of the middle-of-the-road scenario is given in ANNEX 2.

5.3.2.2 Scenario 2 “best case”

The best case is based on scenario 1, but assumes realistic positive effects as described in 4.2.2 Scenario 2 “best case” (25% non-repayable funding, CO2 certificates etc.). In addition to the proposed positive effects other frame conditions could add revenues, but are less realistic today and were not taken into account. One of these is the possibility to sell the HTC-process water as liquid fertilizer or even as water for irrigation or potable water (after proper treatment) in arid regions.

Based on the above described assumptions following financial parameters were derived after taxes based on capital (equity + debt):

Table 9. Financial Output Parameters scenario 2 (best case).

Financial Output Parameters	Scenario 2
IRR	14.04 %
NPV	1008 kEUR
Pay back period in years	10 years
Average DSCR	2.24x
Minimum DSCR	1.92x
Break Even HTC-Coal Price	191.23 EUR

The financial parameters are more attractive compared to the base case in scenario 1. Interestingly, the break even HTC-Coal price is slightly below the estimated HTC-Coal price in scenario 3. As described in 4.2.3 Scenario 3 “worst case”, the HTC-Coal price was set according to the actual market price of wood pellets taking the different lower heating value of the HTC-Coal into account (193 €/to). Thus if a non-refundable funding could be achieved for the landmark project and CO2 certificates sold for a moderate price, the HTC-Coal pellets would be already competitive under current conditions. These assumptions are not unreasonable as up to date no HTC-Pilot Plat is in operation so far, which could favor the first HTC-plant for public funding and a conservative price for CO2-certificates was assumed (6 €/to CO2).

The sensitivity of the IRR with respect to the variation of different parameters is different compared to scenario 1 (base case). The increases of the IRR due to the positive effects are similar to reductions of the IRR due to negative developments.

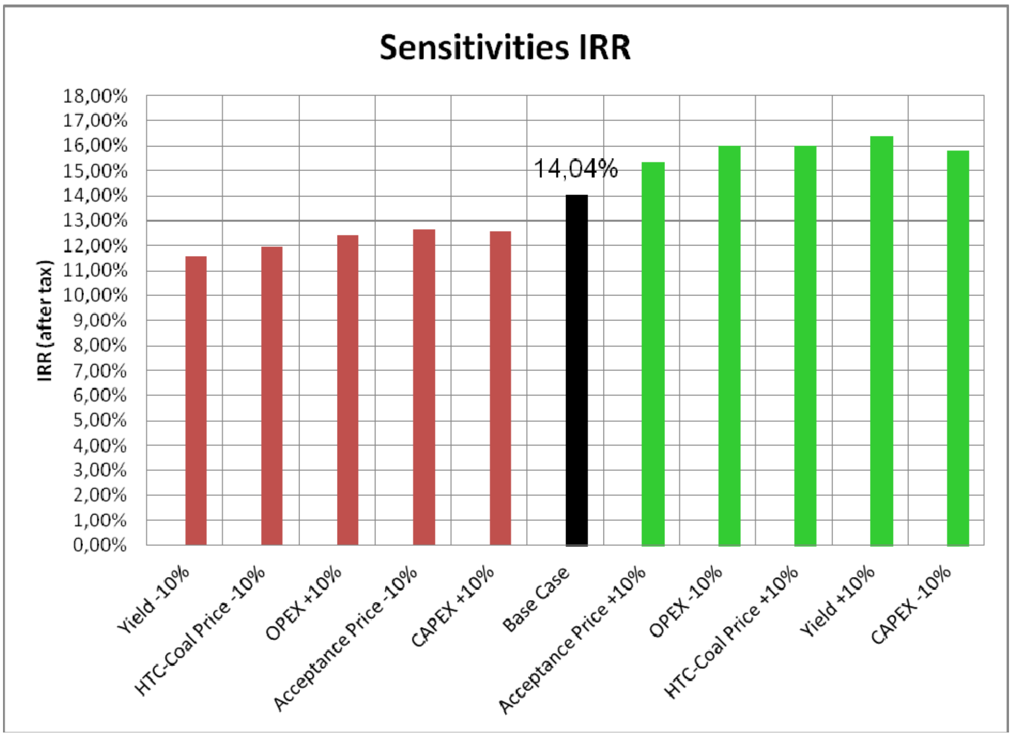

Figure 20. IRR sensitivities of scenario 2.

As described above, a reduction on yield or HTC-Coal price would have the largest negative impact on the IRR, which is similar to scenario 1. Slightly different to scenario 1 is the ranking of the elasticity of the IRR depending on different parameter changes.

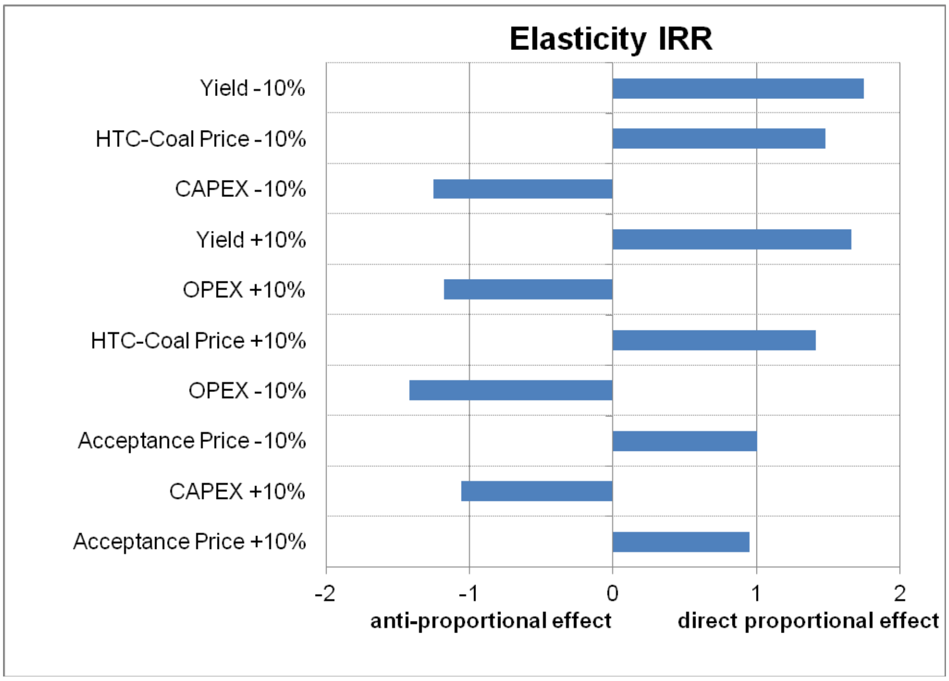

Figure 21. Elasticity values for different sensitivities for scenario 2.

By evaluating the impact of parameter changes on the NPV, it is shown in Figure 22 that a negative development of the parameters still results in a positive project. In addition, the respective IRRs are still in a reasonable range.

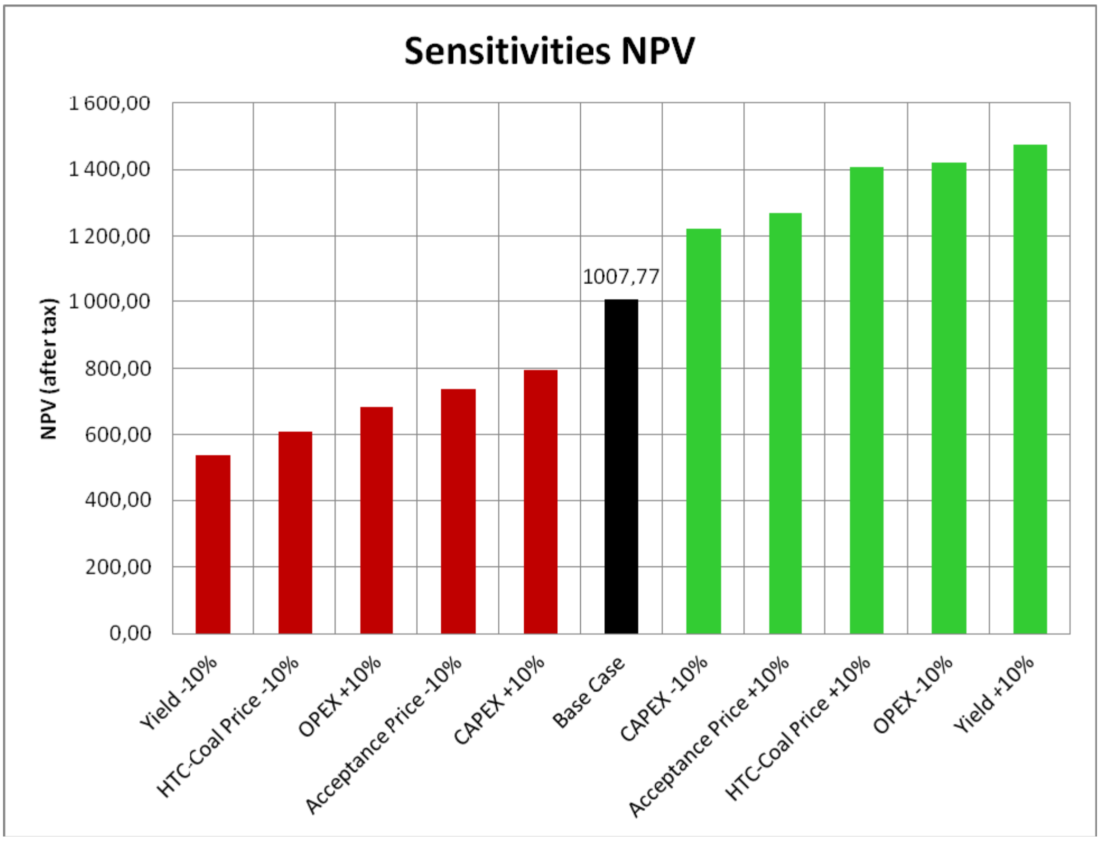

Figure 22. NPV sensitivities of scenario 2.

Detailed information of the financial model of scenario 2 is given in ANNEX 3.

5.3.2.3 Scenario 3 “worst case”

The general assumptions for scenario 3 are the same as for scenario 1 (middle-of-the-road) and 2 (best case). Different to scenario 1 is the achievable price for the produced HTC-Coal pellets. In this scenario it has been assumed, that HTC-coal has to compete on the fuel-market directly with wood pellets. Thus, the HTC-coal pellet price was set equal to the one for wood-pellets (January 2012) [11], but taking into account the slightly lower heating value of the HTC-Coal (~15 700 kJ/kg)

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[11] Pro Pellets Austria: Energieträger im Vergleich, Stand März 2012.

produced form the feedstock assumed in this study (5000 to/a horse dung, 2500 to/a leftovers, 2500 to/a grass&foliage).

Based on the above described assumptions following financial parameters were derived for scenario 3 after taxes based on capital (equity + debt):

Table 10. Financial Output Parameters scenario 3 (worst case).

Financial Output Parameters	**Scenario 2**
IRR	3.81 %
NPV	-943 kEUR
Pay back period in years	no value years
Average DSCR	1.04x
Minimum DSCR	0.50x
Break Even HTC-Coal Price	238.64 EUR

It has already been shown in the sensitivity analysis of scenario 1 that a reduction of the HTC-Coal price leads to a negative project (negative NPV). However, the most interesting information of this scenario is its sensitivity to positive changes.

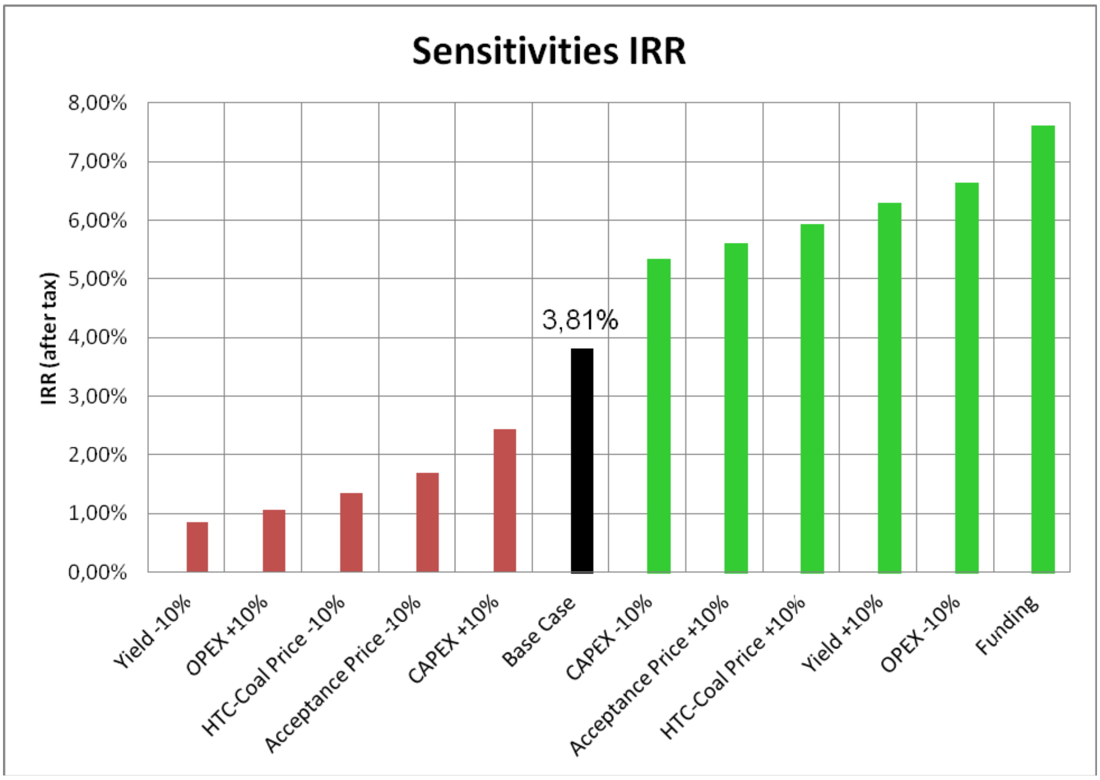

Figure 23. IRR sensitivities of scenario 3.

As it is shown in Figure 23, the negative impacts of unfavorable developments are much stronger compared to the possible positive impacts on the IRR. A reduction of 10% of the yield or an increase of 10% of the OPEX would reduce the IRR of scenario 3 to more than one third. But reasonable IRRs can be achieved even with the assumed HTC-Coal price if only one of the varied input parameters develops more positively. However, even with a proposed funding, it is not possible to receive a positive NPV.

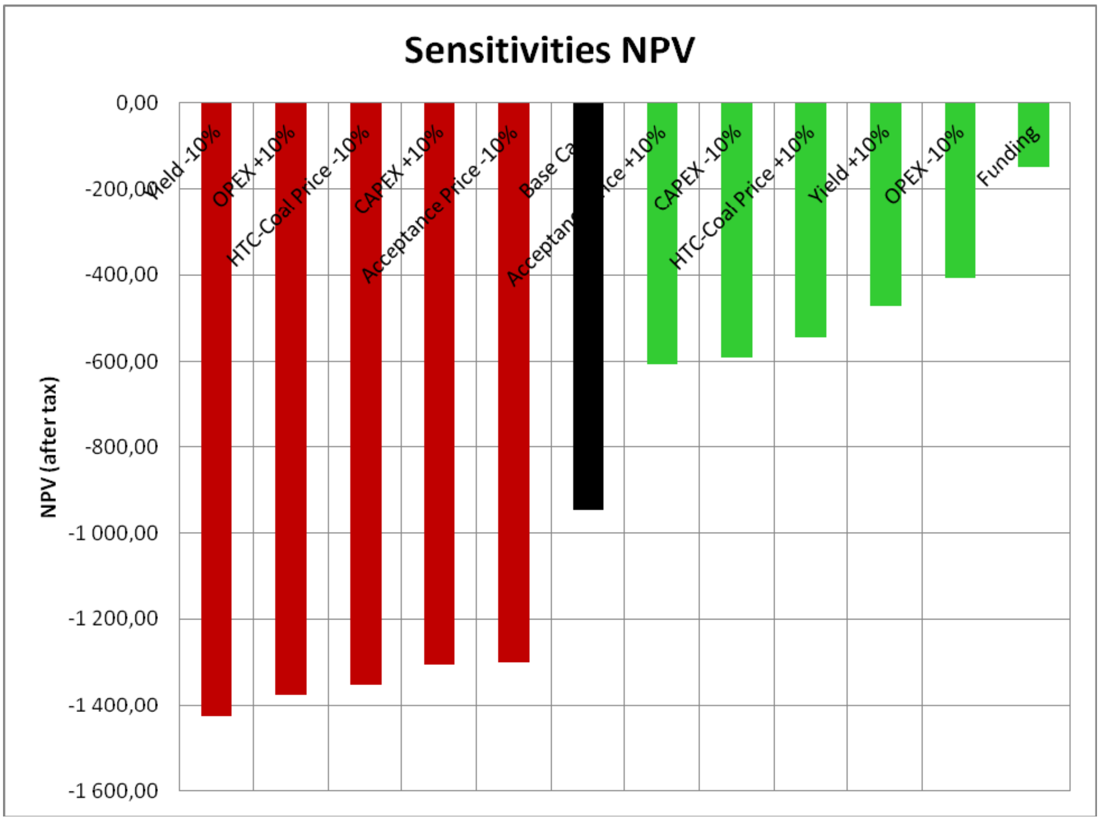

Figure 24. NPV sensitivities of scenario 2.

More detailed information of the financial model regarding scenario 3 is given in ANNEX 4.

6 Conclusions

The core objective of this study was to review the technical and financial feasibility of hydrothermal carbonization for the conversion of biowaste.

Based on the available scientific publications and feedback from HTC-Process plant vendors, it has been shown in this study that hydrothermal carbonization has the ability to treat organic waste under mild process conditions. The reaction takes place in pure water at elevated temperatures (170°C-250°C) without employing any hazardous additives (e.g. surfactants or catalysts). The great advantage of HTC seems to be its ability to treat every kind of biomass without restrictions regarding water content or biological structure. Although, the market entry of the HTC process will be via waste treatment projects, it is the huge variety of the HTC-products which is the main attractiveness of the HTC-process on the long term. It is a green and sustainable alternative for the production of solid particles or high surface area scaffolds with a surface that can be tuned by polar functional groups. Beside the general application as biocoal, more sophisticated products for catalysis, adsorption and energy storage could be produced via HTC (Titirici 2010).

Another aspect of the HTC process is its ability to produce fertile soil and water, two resources which are already of high value in arid regions, but are getting more and more in the main focus of the European Commission, as outlined in their flagship initiative on “A Resource Efficient Europe” (European Commission 2011). Thus, as organic waste, loss of fertile soil and water scarcity becomes a serious issue within the European Union, hydrothermal carbonization provides a feasible solution to address these issues of our near future.

As with every emerging technology, hydrothermal carbonization is currently hardly a competitive stand alone process on the open market. But if the process can be implemented in an existing infrastructure e.g. compost plant, sewage plant or other businesses which are confronted with large amounts of wet organic waste, HTC is already today a financially feasible process (Escala 2011, Rakelmann 2009).

All together, HTC offers not only a new green and sustainable technology for the treatment of biowaste. It is a promising research and development field leading to new functional materials based on renewable resources.

Acknowledgements

First of all I want to thank ILF Consulting Engineers and especially Mr. Klaus Lässer, for giving me the opportunity to work on the edge of new innovations.
Many thanks also to Prof. Hermann Hofbauer, who inspired me with his “biomass activities” to get involved in this topic.
Mr. Walter Deckardt I would like to thank for giving the insight into the processing of compost. With his support, this study got the necessary realistic input.
A source of great inspiration for the hydrothermal carbonization topic were Mr. Dave Tjiok and all the other colleagues from the HTC-Netzwerk. I am convinced that our joint effort to promote HTC will finally result in a couple of interesting projects.
Great support was also given by my MSc colleague Markus Satzer, who helped me setting up and understanding my financial model.

Last but not least, I am grateful to have the opportunity to rise with my wonderful wife two lovely children how made it both despite their accident of birth. It is great to have a relation with them, which is best characterized by its familiarity, inspiration, respect and bliss. Experiencing this every day reminds me, that we can and should do better.
About one century ago Friedrich Bergius got the Nobel Prize for the basic discovery of the HTC process. It’s time to get on his track again and innovate for man’s sake.

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8 Annexes

ANNEX 1: Questionnaire for HTC-plant vendors.

ANNEX 2: Financial Model “middle-of-road”.

ANNEX 3: Financial Model “best case”.

ANNEX 4: Financial Model “worst case”.

ANNEX 5: Simplified Flow Diagram of case model.

ANNEX 1

Datenerfassungsbogen

Wirtschaftlichkeitsanalyse 10.000 t/a HTC-Anlage
(50% Pferdemist, 50% Grünschnitt u. Biotonne)

Firma

Ansprechpartner

e-mail

Telefon

Projektstandort	Bezirk Tulln, Österreich
Anlage	derzeit Kompostieranlage
Anlagenkapazität für Analyse	10000 t/a

Stoffzusammensetzung *Anm.: Annahme für Studie*	
Pferdemist (50% Strohstreu, 50% Sägespäne-Streu)	5000 t/a
Biotonnenmaterial *Anm.: Sommer (90% Gartenabfälle, 10% Haushaltsabfälle)* *Winter (10% Gartenabfälle, 90% Haushaltsabfälle)*	3000 t/a
Holz (Strauchschnitt, Wurzelstöcke, Holzabfälle)	1000 t/a
Gras und Laub	1000 t/a

Rückmeldungen bitte an:

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Email: Walter.Tesch@ilf.com ; Webpage: www.ilf.com

Angaben zum HTC-Verfahren/Gesamtanlage

Gesamtanlage (Aufbereitung, HTC, Nachbereitung/Phasentrennung, Pelletierung)		
Energiebilanz	Bitte Blockdiagramm zur Verfügung stellen.	
Platzbedarf		m²
Anlagenverfügbarkeit		%
Betriebsstunden pro Jahr		h/a
Anlagenlebensdauer		a
Wartungsintervalle pro Jahr (unterjährig)		/a
Wartungsdauer pro Intervall (unterjährig)		h
Wartungsintervalle pro Jahr (überjährig)		/a
Wartungsdauer pro Intervall (überjährig)		h
erforderliches Anlagepersonal (Qualifikationen, Anzahl)		
empfohlene Lagerkapazität für aufbereiteten Einsatzstoff		
empfohlene Lagerkapazität für Pellets		
empfohlene Lagerkapazität für Reaktionswasser		
Empfohlene Ersatzteilhaltung für 2 jährigen Betrieb		

sonstige Bemerkungen:

Rückmeldungen bitte an:
Dr. Walter Tesch
Mobile: +43 699 1453 0222; **Walter.Tesch@ilf.com**

Angaben zum HTC-Verfahren/Gesamtanlage

HTC-Verfahren	
Arbeitstemperatur	°C
Arbeitsdruck	bar
erforderlicher pH Wert	
erforderliche Zusatzstoffe	
Wassergehalt Einsatzstoff	%
max. Teilchengröße des eingesetzten Materials nach Aufbereitung der Einsatzstoffe	mm
max. zulässiger Erdanteil	%
sonstige Anforderungen (Fremdstoffgehalte, Variationsmöglichkeiten Aufgabematerial,….)	

sonstige Bemerkungen:

Rückmeldungen bitte an:

Dr. Walter Tesch

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Betriebsmittelbedarf

Rohstoff-Aufbereitung	
Strom (Anschlußleistung?)	kWh/a
Frischwasserbedarf für Prozeß	m³/a
Kühlwasserbedarf	m³/a
Sonstige Betriebsmittel (Chemikalien,…)	kg/a
HTC-Anlage	
Strom (Anschlußleistung?)	kWh/a
Dampf (Druckstufe, Temperatur?) *Anm.: zur Dampferzeugung steht lediglich Biomasse (Hackschnitzel) zur Verfügung (kein Gasanschluß etc.)*	t/a
Frischwasserbedarf für Prozeß	m³/a
Kühlwasserbedarf	m³/a
Sonstige Betriebsmittel (Chemikalien,…)	kg/a
Nachbereitung/Phasentrennung	
Strom (Anschlußleistung?)	kWh/a
Frischwasserbedarf für Prozeß	m³/a
Kühlwasserbedarf	m³/a
Sonstige Betriebsmittel (Chemikalien,…)	kg/a
Pelletierung	
Strom (Anschlußleistung?)	kWh/a
Frischwasserbedarf für Prozeß	m³/a
Kühlwasserbedarf	m³/a
Sonstige Betriebsmittel (Chemikalien,…)	kg/a

Rückmeldungen bitte an:
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Produktangaben

Kohlepellets	
Ausbeute	t/a
Unterer Heizwert Hu	MJ/kg
Wassergehalt	%
Aschegehalt	%
Ascheschmelzpunkt	℃
Schwefel-Gehalt	mg/t
Stickstoff-Gehalt	mg/t
Chlor-Gehalt	mg/t
Presshilfsmittel	%
Abrieb	%
Teilchendichte	m³/t
Reaktionswasser	
Menge	m³/a
pH-Wert	
C/N-Verhältnis	
TOC	mg TOC/l
CSB	mg O2/l
sonstige Inhaltsstoffe	
Abgase?	
CO2 ?	m³/a
sonstige Abgase	m³/a
Verwertbare Abwärme (Temperatur?)	kWh/a

Rückmeldungen bitte an:
Dr. Walter Tesch
Mobile: +43 699 1453 0222; **Walter.Tesch@ilf.com**

Kosten

Investmentkosten	
Aufbereitung	EUR
HTC-Anlage	EUR
Nachbereitung/Phasentrennung	EUR
Pelletierung	EUR
Chemikalienlager	EUR
Lager für Pellets	EUR
Lager für Reaktionswasser	EUR
sonstige Infrastruktur	EUR
Ersatzteilkosten für 2 jährigen Betrieb	EUR
Gesamtanlage (Vorbereitung, HTC, Nachbereitung, Pelletierung)	
Wartungskosten	EUR/a
Wartungskosten (überjährig, wie oft innerhalb Anlagenlebensdauer?)	EUR
Reparaturvorsorgekosten	EUR/a

sonstige Bemerkungen:

ANNEX 2

HTC Plant for compost works (best guess)

Input Data

All Figures in EUR unless otherwise stated No. of Errors 0

Base Case

1

PROJECT IDENTIFICATION		
Project Name		**HTC Plant for compost works (best guess)**
Project Location		Lower Austria
Project Country		Austria
Name of Project Company		Compost Test Company
Legal Form of Project Company		GmbH
Country of Origin		Austria
MODEL SETTINGS		
Language Selection	1=Deutsch; 2=English	2
Business Plan Currency		EUR
Additional Reporting-Currency		none
Installed Plant Capacity		No = 0 / Yes = 1
Feedstock Processing Capacity	**10000,0 to/a**	**1**
PURCHASE PARAMETERS		
CAPEX	EUR/to/a	340
Contingencies	EUR/to/a	34
Construction Cost (net)	**EUR/to/a**	**374**
% eligible costs for grant	%	0,00%
Total Initial Investment	**kEUR**	**3 740**
INFLATION & ESCALATION RATES		
Inflation	% pa	2,00%
Escalation rate utilities	% pa	2,00%
Escalation rate personal	% pa	2,00%
Discount Factor	% pa	8,50%
TIME SCHEDULE (semi-annual)		
Price Basis for Cost Assumptions	Year	01.01.2012
Start of Construction	Date	01.07.2012
Construction Period	onths (shortest period 6 mo)	6
Start of Operation	Date	01.01.2013
Operation Period	Years	20
TIMELINE FOR BUSINESS PLAN		
Start Date Timeline	Date	01.01.2012

HTC Plant for compost works (best guess)

Input Data

All Figures in EUR unless otherwise stated No. of Errors 0

Base Case

1

POSITIONS RELEVANT TO INCOME ACCOUNT			
Feedstock	Acceptance of sludge	to/a	0,00
	Acceptance of leftovers	to/a	2 500,00
	Acceptance horse dung	to/a	5 000,00
	Acceptance wooden material	to/a	0,00
	Acceptance grass & foliage	to/a	2 500,00
	Acceptance Educt 1	to/a	0,00
	Acceptance Educt 2	to/a	0,00
Products	**HTC-coal**	No = 0/Yes =1	1
	HTC-coal (sludge)	to/a	0,00
	HTC-coal (leftovers)	to/a	581,53
	HTC-coal (horse dung)	to/a	1 123,61
	HTC-coal (wooden material)	to/a	0,00
	HTC-coal (grass & foliage)	to/a	604,42
	HTC-coal (educt 1)	to/a	0,00
	HTC-coal (educt 2)	to/a	0,00
	HTC-process water	No = 0/Yes =1	0
	HTC-process water (sludge)	to/a	0,00
	HTC-process water (leftovers)	to/a	0,00
	HTC-process water (horse dung)	to/a	0,00
	HTC-process water (wooden material)	to/a	0,00
	HTC-process water (grass & foliage)	to/a	0,00
	HTC-process water (educt 1)	to/a	0,00
	HTC-process water (educt 2)	to/a	0,00
others	**Heat (export)**	No = 0/Yes =1	1
	Heat (export)	MWh/a	3 659,31
	CO2-Certificates	No = 0/Yes =1	0
	CO2-Certificates	to/a	0,00
	Other Revenues	No = 0/Yes =1	0
	Revenue position 1	to/a	0,00
	Revenue position 2	to/a	0,00
	Revenue position 3	to/a	0,00
	Revenue position 4	to/a	0,00

HTC Plant for compost works (best guess)

Input Data

All Figures in EUR unless otherwise stated

No. of Errors 0

Base Case

1

SALES PRICE ASSUMPTIONS		
Acceptance of sludge	EUR/to	35,00
Acceptance of leftovers	EUR/to	40,00
Acceptance horse dung	EUR/to	37,00
Acceptance wooden material	EUR/to	25,00
Acceptance grass & foliage	EUR/to	34,00
Acceptance Educt 1	EUR/to	0,00
Acceptance Educt 2	EUR/to	0,00
HTC-coal (sludge)	EUR/to	240,00
HTC-coal (leftovers)	EUR/to	240,00
HTC-coal (horse dung)	EUR/to	240,00
HTC-coal (wooden material)	EUR/to	240,00
HTC-coal (grass & foliage)	EUR/to	240,00
HTC-coal (educt 1)	EUR/to	240,00
HTC-coal (educt 2)	EUR/to	240,00
HTC-process water (sludge)	EUR/to	1,00
HTC-process water (leftovers)	EUR/to	1,00
HTC-process water (horse dung)	EUR/to	1,00
HTC-process water (wooden material)	EUR/to	1,00
HTC-process water (grass & foliage)	EUR/to	1,00
HTC-process water (educt 1)	EUR/to	1,00
HTC-process water (educt 2)	EUR/to	1,00
Heat (export)	EUR/MWh	22,00
CO2-Certificates	EUR/to	6,00
Revenue position 1	EUR/to	1,00
Revenue position 2	EUR/to	1,00
Revenue position 3	EUR/to	1,00
Revenue position 4	EUR/to	1,00

HTC Plant for compost works (best guess)

Input Data

All Figures in EUR unless otherwise stated No. of Errors 0

Base Case

1

OPERATING COSTS		
Operator/Management		
Operator 1	h/a	2 080,00
hourly rate operator 1	EUR/h	20,00
Operator 2	h/a	2 080,00
hourly rate operator 2	EUR/h	25,00
Management	h/a	208,00
hourly rate management	EUR/h	55,00
Operator/Management costs total per year	**EUR/a**	**105 040**
Utilities consumption		
Gas	kWh/a	0,00
Biomass	to/a	1 121,21
Electricity	kWh/a	750 000
Fresh water	m³/a	4 500
Waste water	m³/a	7 921,40
Chemicals	kg/a	200
Utilities Costs		
Gas	EUR/kWh	0,04
Biomass	EUR/to	100,00
Electricity	EUR/kWh	0,13
Fresh water	EUR/m³	1,50
Waste water	EUR/m³	3,50
Chemicals	EUR/kg	50,00
Total utilities consumption cost per year	**EUR/a**	254 096,12
Operation (external)		
Feedstock preparation (external; e.g. shredde	EUR/a	10 000,00
Maintenance	EUR/a	74 800,00
Miscellaneous 2	EUR/a	0,00
Total external operational costs per year	**EUR/a**	**84 800,00**
Land lease	EUR/a	15 000,00
Insurance	EUR/a	37 400,00
Contingencies	EUR/a	22 196,81
Operational Expenditure (OPEX) per year	**EUR/a**	**518 533**
WORKING CAPITAL		
Accounts Receivable	Days	30
Accounts Payable	Days	30

CONSULTING ENGINEERS

HTC Plant for compost works (best guess)

Input Data

All Figures in EUR unless otherwise stated No. of Errors 0

Base Case

1

DEPRECIATION & AMORTIZATION		
Components (Depreciation 20 Years)	Years	20
Components (Depreciation 10 Years)	Years	10
Components (Depreciation 5 Years)	Years	5
Components (Depreciation 1 Years)	Years	1
Start Depreciation (Depreciation 20 Years)	Date	01.01.2013
Start Depreciation (Depreciation 10 Years)	Date	01.01.2013
Start Depreciation (Depreciation 5 Years)	Date	01.01.2013
Start Depreciation (Depreciation 1 Years)	Date	01.01.2013
Components (Depreciation 20 Years)	%	70,00%
Components (Depreciation 10 Years)	%	30,00%
Components (Depreciation 5 Years)	%	0,00%
Components (Depreciation 1 Years)	%	0,00%
	Check	*0*
TAXES		
Corp. Income Tax	%	25,00%
Reserve Accounts		
Interest on Reserve Accounts	% pa	1,20%
Funding		
Equity	%	25%
Repayment of Equity	No = 0/Yes =1	1
Repayment of Bullet in operating Year	Date	01.01.2012
Long term loan	%	75%
Interest on Loan	%	4%
Repayment of loan (start)	Date	01.01.2014
REINVESTMENT RESERVE		
	% of Investment Volume	1,00%
Profit Distribution		
Share on free cash after tax and financing	%	75%
Profit Distribution	No = 0/Yes =1	1

HTC Plant for compost works (best guess)

Output

All Figures in EUR unless otherwise stated

Base Case

	Unit	Total	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Construction	flags	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operation	flags	20	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Operating Year	counter	20	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	0	0	0	0	0	0	0	0	0	0
PROFIT & LOSS ACCOUNT																																	
Revenue from Feedstock Acceptance	kEUR	7 492,50	92,50	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Revenue from HTC-coal	kEUR	11 085,86	0,00	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	554,29	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Revenue from HTC-process water	kEUR	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Revenue from other positions	kEUR	1 610,09	0,00	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
TOTAL TURNOVER	kEUR	20 188	93	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	0	0	0	0	0	0	0	0	0	0
Operator/Management costs total per year	kEUR	-2 643,07	-26,52	-107,68	-109,83	-112,03	-114,27	-116,56	-118,89	-121,27	-123,70	-126,17	-128,70	-131,27	-133,90	-136,58	-139,31	-142,10	-144,94	-147,85	-150,80	-153,82	-156,90	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total utilities consumption cost per year	kEUR	-6 329,55	0,00	-260,47	-265,68	-270,99	-276,42	-281,96	-287,60	-293,35	-299,22	-305,22	-311,32	-317,55	-323,91	-330,39	-337,00	-343,74	-350,63	-357,65	-364,80	-372,10	-379,55	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total external operational costs per year	kEUR	-2 112,37	0,00	-86,93	-88,67	-90,44	-92,25	-94,10	-95,98	-97,90	-99,86	-101,86	-103,90	-105,98	-108,10	-110,26	-112,47	-114,72	-117,02	-119,36	-121,75	-124,18	-126,67	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Land lease	kEUR	-381,23	-7,57	-15,38	-15,68	-16,00	-16,32	-16,64	-16,98	-17,32	-17,66	-18,02	-18,38	-18,75	-19,12	-19,50	-19,89	-20,29	-20,70	-21,11	-21,54	-21,97	-22,41	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Insurance	kEUR	-931,64	0,00	-38,34	-39,11	-39,89	-40,69	-41,50	-42,33	-43,18	-44,04	-44,92	-45,82	-46,74	-47,68	-48,63	-49,60	-50,59	-51,61	-52,64	-53,69	-54,77	-55,87	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Contingencies	kEUR	-552,92	0,00	-22,75	-23,21	-23,67	-24,15	-24,63	-25,12	-25,63	-26,14	-26,66	-27,20	-27,74	-28,30	-28,86	-29,44	-30,03	-30,63	-31,24	-31,87	-32,50	-33,16	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Depreciation	kEUR	-3 740	0	-243	-243	-243	-243	-243	-243	-243	-243	-243	-243	-131	-131	-131	-131	-131	-131	-131	-131	-131	-131	0	0	0	0	0	0	0	0	0	0
EARNINGS BEFORE INTEREST & TAXES (EBIT)	kEUR	3 498	58	230	220	209	198	186	175	163	151	139	126	226	213	200	186	172	158	144	129	115	99	0	0	0	0	0	0	0	0	0	0
EBIT Margin			*63%*	*23%*	*22%*	*21%*	*20%*	*19%*	*17%*	*16%*	*15%*	*14%*	*13%*	*22%*	*21%*	*20%*	*19%*	*17%*	*16%*	*14%*	*13%*	*11%*	*10%*										
Interest on Loan	kEUR	-1 146	0	-107	-105	-100	-94	-88	-83	-77	-72	-66	-60	-55	-49	-43	-38	-32	-27	-21	-15	-10	-4	0	0	0	0	0	0	0	0	0	0
Interest on Reserve Accounts	kEUR	369	0	1	4	6	8	10	12	14	15	17	19	20	22	23	25	26	27	28	29	30	31	0	0	0	0	0	0	0	0	0	0
Result from Ordinary Operations	kEUR	2 720	58	125	118	115	112	108	104	100	95	90	85	192	186	179	173	166	159	151	143	135	126	0	0	0	0	0	0	0	0	0	0
Corporate Income Tax	kEUR	-58	-15	-31	0	0	0	0	0	0	0	0	0	-6	-4	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PROFIT / LOSS FOR THE YEAR (NIAT)	kEUR	2 662	44	94	118	115	112	108	104	100	95	90	85	186	182	177	173	166	159	151	143	135	126	0	0	0	0	0	0	0	0	0	0
	Check	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
CASH FLOW																																	
TOTAL TURNOVER	kEUR	20 188	93	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	1 005	0	0	0	0	0	0	0	0	0	0
Operating Expenditures	kEUR	-12 950,77	-34,10	-531,54	-542,17	-553,02	-564,09	-575,39	-586,90	-598,64	-610,62	-622,85	-635,31	-648,02	-661,00	-674,23	-687,72	-701,47	-715,52	-729,85	-744,45	-759,34	-774,55	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Change in Working Capital	kEUR	0	-10	-29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19	0	0	0	0	0	0	0	0	0
CASH FLOW FROM OPERATIONS PRE TAX	kEUR	7 238	49	444	464	453	442	430	419	407	395	383	371	358	345	332	318	304	290	276	262	247	232	19	0	0	0	0	0	0	0	0	0
Income Taxes	kEUR	-58	-15	-31	0	0	0	0	0	0	0	0	0	-6	-4	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CASH FLOW FROM OPERATIONS AFTER TAX	kEUR	7 180	34	413	464	453	442	430	419	407	395	383	371	352	341	330	318	304	290	276	262	247	232	19	0	0	0	0	0	0	0	0	0
CASH FLOW FROM INVESTMENTS	kEUR	-3 740	-3 740	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paid in Share Capital	kEUR	3 740	3 740	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Repayment of Equity	kEUR	-935	0	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	0	0	0	0	0	0	0	0	0	0
CASH FLOW FROM FINANCING	kEUR	2 805	3 740	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	0	0	0	0	0	0	0	0	0	0
CASH FLOW AFTER TAXES BEFORE DEBT SERVICE	kEUR	6 245	34	367	417	406	395	384	372	360	348	336	324	305	294	283	271	258	244	229	215	200	185	19	0	0	0	0	0	0	0	0	0
Repayment of Debt	kEUR	-2 805,00	0,00	0,00	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Interest on Loan	kEUR	-1 145,84	0,00	-106,59	-105,19	-99,58	-93,97	-88,36	-82,75	-77,14	-71,53	-65,92	-60,31	-54,70	-49,09	-43,48	-37,87	-32,26	-26,65	-21,04	-15,43	-9,82	-4,21	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Interest on Reserve Accounts	kEUR	369	0	1	4	6	8	10	12	14	15	17	19	20	22	23	25	26	27	28	29	30	31	0	0	0	0	0	0	0	0	0	0
Change in Reinvestment Reserve	kEUR	0	0	-37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	0	0	0	0	0	0	0	0	0
FREE CASH FLOW AFTER TAXES AND FINANCING	kEUR	2 662	34	224	168	165	161	158	154	149	145	140	135	123	119	115	110	104	97	89	81	73	101	19	0	0	0	0	0	0	0	0	0
FREE CASH FLOW AFTER TAXES, FINANCING AND PROFIT DISTRIBUTION	kEUR	0	34	224	105	41	40	39	38	37	36	35	34	31	30	29	28	26	24	22	20	18	25	-918	0	0	0	0	0	0	0	0	0
CUMULATED FREE CASH FLOW AFTER TAXES, FINANCING AND PROFIT DISTRIBUTION	kEUR		34	258	363	404	445	484	522	560	596	631	665	695	725	754	781	807	832	854	874	892	918	0	0	0	0	0	0	0	0	0	0
	check																																
BALANCE SHEET																																	
Assets																																	
Fixed Assets	kEUR	33 660	3 740	3 497	3 254	3 011	2 768	2 525	2 281	2 038	1 795	1 552	1 309	1 178	1 047	916	785	655	524	393	262	131	0	0	0	0	0	0	0	0	0	0	0
Current Assets																																	
Receivables	kEUR	1 667	15	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	0	0	0	0	0	0	0	0	0	0
Cash in Hand & Bank Deposits	kEUR	31 993	34	258	426	591	752	909	1 063	1 212	1 357	1 497	1 631	1 755	1 874	1 989	2 099	2 203	2 299	2 388	2 470	2 542	2 644	0	0	0	0	0	0	0	0	0	0
Reinvestment Reserve	kEUR	711	0	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	0	0	0	0	0	0	0	0	0	0	0
Total Assets	kEUR	68 031	3 789	3 875	3 800	3 721	3 639	3 554	3 464	3 371	3 272	3 169	3 060	3 053	3 041	3 025	3 004	2 977	2 943	2 901	2 851	2 793	2 726	0	0	0	0	0	0	0	0	0	0
Liabilities																																	
Equity																																	
Paid-in Share Capital	kEUR		935	888	842	795	748	701	655	608	561	514	468	421	374	327	281	234	187	140	94	47	0	0	0	0	0	0	0	0	0	0	0
Drawn Debt	kEUR		2 805	2 805	2 657	2 510	2 362	2 214	2 067	1 919	1 772	1 624	1 476	1 329	1 181	1 033	886	738	591	443	295	148	0	0	0	0	0	0	0	0	0	0	0
Profit / Loss carried forward	kEUR		0	91	197	314	427	537	643	745	842	935	1 022	1 157	1 341	1 521	1 696	1 865	2 028	2 183	2 330	2 470	2 600	0	0	0	0	0	0	0	0	0	0
Profit / Loss for the Year	kEUR	1 340	44	46	59	57	55	53	51	49	47	44	42	92	90	88	86	82	79	75	71	66	62	0	0	0	0	0	0	0	0	0	0
Liabilities																																	
from trade payables	kEUR	1 072	6	44	45	46	47	48	48	49	50	51	52	54	55	56	57	58	59	60	61	63	64	0	0	0	0	0	0	0	0	0	0
Total Liabilities	kEUR	68 031	3 789	3 875	3 800	3 721	3 639	3 554	3 464	3 371	3 272	3 169	3 060	3 053	3 041	3 025	3 004	2 977	2 943	2 901	2 851	2 793	2 726	0	0	0	0	0	0	0	0	0	0
	Checksum	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

HTC Plant for compost works (best guess)

RATIOS

All Figures in EUR unless otherwise stated

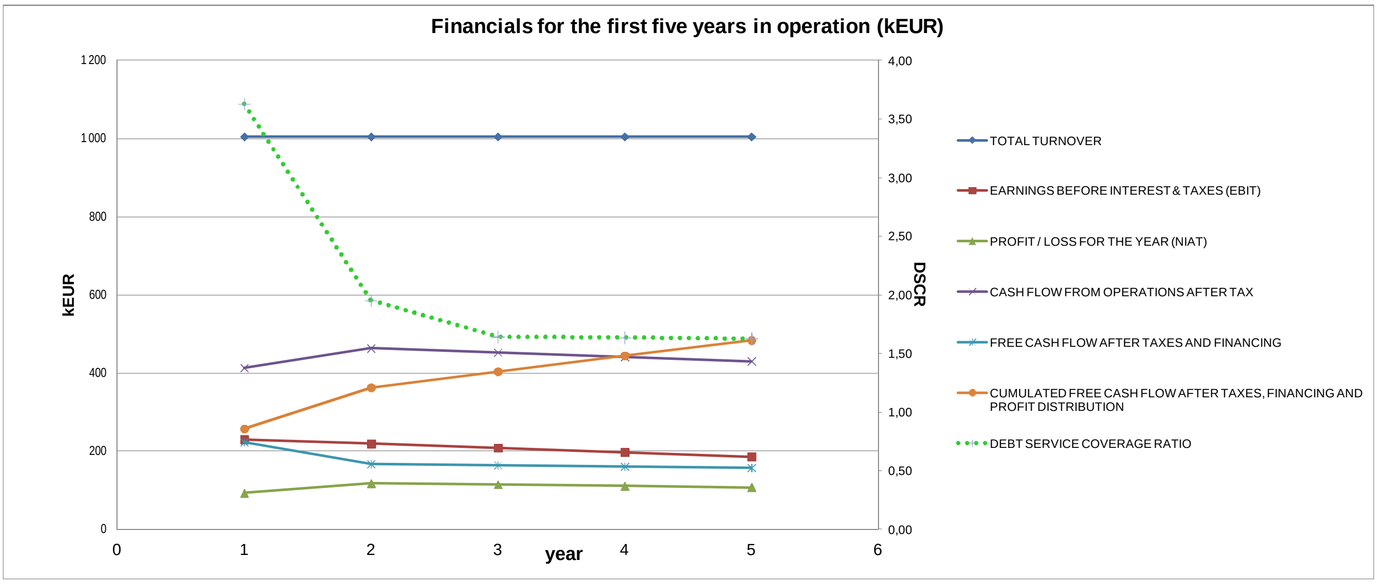
Base Case Errors: 0

Input Data		
Project Parameters		
Price Basis for Cost Assumptions	01.01.2012	Year
Start of Construction	01.07.2012	Date
Construction Period	6,00	Month
Start of Operation	01.01.2013	Date
Operation Period	20,00	Years
Feedstock Processing Capacity	10 000,00	to/a
Feedstock Composition		
Leftovers	2 500,00	to/a
Horse Dung	5 000,00	to/a
Grass & Foilage	2 500,00	to/a
Products		
HTC-coal (leftovers)	581,53	to/a
HTC-coal (horse dung)	1 123,61	to/a
HTC-coal (grass & foliage)	604,42	to/a
HTC-process water (leftovers)	0,00	to/a
HTC-process water (horse dung)	0,00	to/a
HTC-process water (grass & foliage)	0,00	to/a
Heat (export)	3 659,31	MWh/a
CO2-Certificates	0,00	to/a
Utility Consumption		
Gas	0,00	kWh/a
Biomass	1 121,21	to/a
Electricity	750 000,00	kWh/a
Fresh water	4 500,00	m³/a
Waste water	7 921,40	m³/a
Chemicals	200,00	kg/a

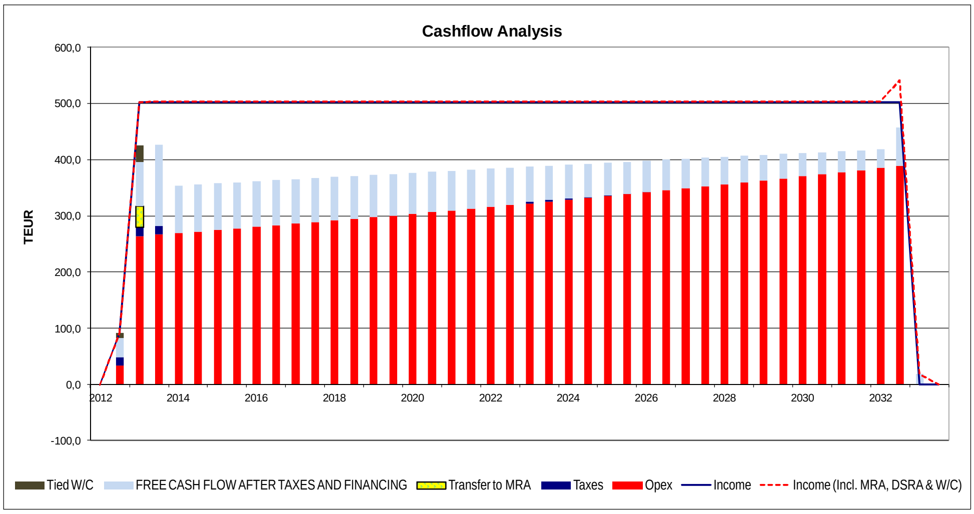
Financial Input Parameters		
Inflation	2,00%	pa
Escalation rate utilities	2,00%	pa
Escalation rate personal	2,00%	pa
Discount Factor	8,50%	pa
Components (Depreciation 20 Years)	70,0%	
Components (Depreciation 10 Years)	30,0%	
Components (Depreciation 5 Years)	0,0%	
Components (Depreciation 1 Years)	0,0%	
Corp. Income Tax	25,0%	
Total Initial Investment	3 740,0	kEUR
Operator/Management costs total per year	105 040,0	EUR/a
Total utilities consumption cost per year	254 096,1	EUR/a
Total external operational costs per year	84 800,0	EUR/a
Operational Expenditure (OPEX) per year	518 532,9	EUR/a

Financial Output Parameters	**Base Case**	
Financials after taxes based on capital (equity + debt):		
IRR	8,63%	
NPV	27	kEUR
Pay back period in years	20	years
Average DSCR	1,58x	
Minimum DSCR	1,22x	
Break Even HTC-Coal Price	238,64	EUR

Financials for the first five years in operation (kEUR)	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**
TOTAL TURNOVER	1 005	1 005	1 005	1 005	1 005
EARNINGS BEFORE INTEREST & TAXES (EBIT)	230	220	209	198	186
PROFIT / LOSS FOR THE YEAR (NIAT)	94	118	115	112	108
CASH FLOW FROM OPERATIONS AFTER TAX	413	464	453	442	430
FREE CASH FLOW AFTER TAXES AND FINANCING	224	168	165	161	158
CUMULATED FREE CASH FLOW AFTER TAXES, FINANCING AND PROFIT DISTRIBU	258	363	404	445	484
DEBT SERVICE COVERAGE RATIO	3,63	1,95	1,64	1,64	1,63

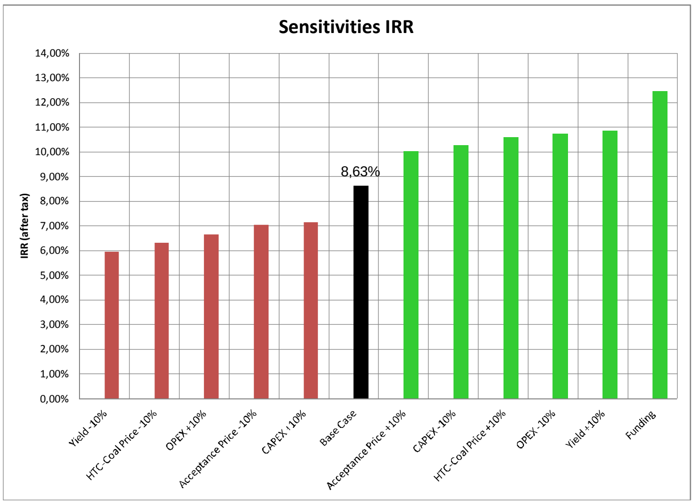


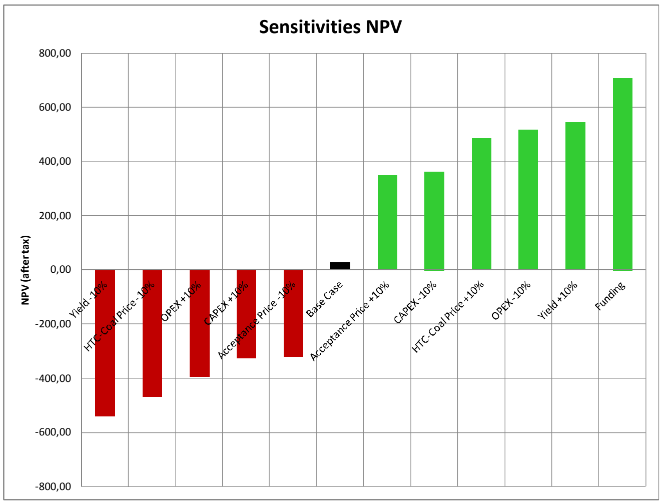
Calculation of semi-annual Returns		
Return on Project		**nominal**
Cashflow before Taxes, before Financing	% p.a.	8,84%
Cashflow after Taxes, before Financing	% p.a.	8,63%
Pay Back Period		
Pay Back Period	Years	20,00
Net Present Value (NPV)		
Discount Factor	% p.a.	8,50%
NPV (after tax)	kEUR	27

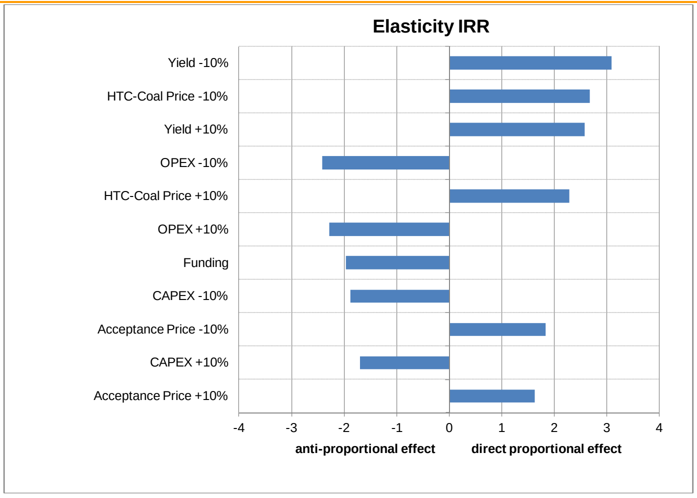


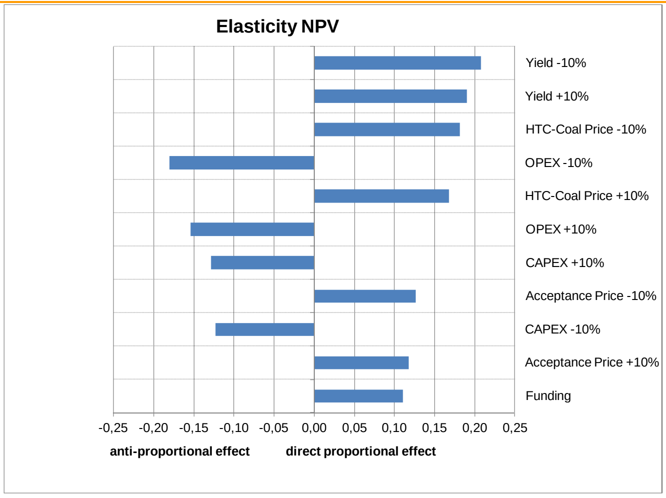
SENSITIVITIES

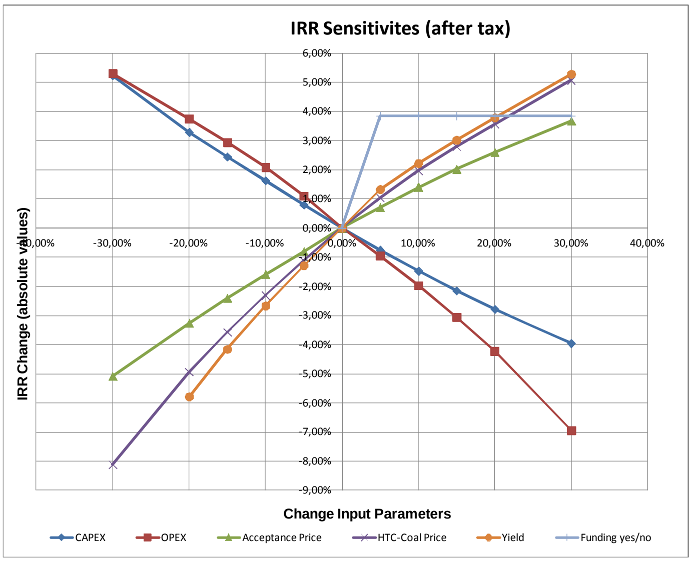
Sensitivities	Input Change	IRR Base Case (after tax)	IRR change (after tax)	rel. Change	IRR Elasticity	NPV Base Case (k€ after tax)	NPV change (k€ after tax)	rel. Change (norm. by /1000)	NPV Elasticity (norm. by /1000)
CAPEX	-10,0%	**8,63%**	10,26%	18,88%	-1,89	27,21	361,6	1,23%	-0,12
	+10,0%		7,16%	-17,04%	-1,70		-323,6	-1,29%	-0,13
OPEX	-10,0%		10,72%	24,24%	-2,42		517,0	1,80%	-0,18
	+10,0%		6,66%	-22,82%	-2,28		-392,7	-1,54%	-0,15
Acceptance Price	-10,0%		7,04%	-18,37%	1,84		-317,8	-1,27%	0,13
	+10,0%		10,03%	16,24%	1,62		347,9	1,18%	0,12
HTC-Coal Price	-10,0%		6,32%	-26,72%	2,67		-466,1	-1,81%	0,18
	+10,0%		10,60%	22,89%	2,29		484,6	1,68%	0,17
HTC-Process Water Price	-10,0%		8,63%	0,00%	0,00		27,2	0,00%	0,00
Price	+10,0%		8,63%	0,00%	0,00		27,2	0,00%	0,00
Yield	-10,0%		5,96%	-30,89%	3,09		-538,4	-2,08%	0,21
	+10,0%		10,85%	25,76%	2,58		543,9	1,90%	0,19
Funding yes/no			12,48%	44,66%	-1,96		708,5	2,50%	0,11

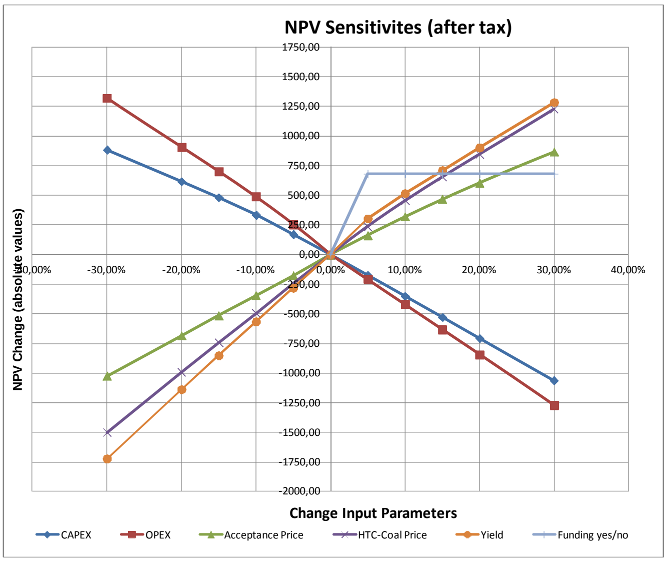












ANNEX 3

HTC Plant for compost works (best guess)

Input Data

All Figures in EUR unless otherwise stated

No. of Errors 0

Base Case

1

PROJECT IDENTIFICATION		
Project Name		**HTC Plant for compost works (best guess)**
Project Location		Lower Austria
Project Country		Austria
Name of Project Company		Compost Test Company
Legal Form of Project Company		GmbH
Country of Origin		Austria
MODEL SETTINGS		
Language Selection	1=Deutsch; 2=English	2
Business Plan Currency		EUR
Additional Reporting-Currency		none
Installed Plant Capacity		No = 0 / Yes = 1
Feedstock Processing Capacity	**10000,0 to/a**	**1**
PURCHASE PARAMETERS		
CAPEX	EUR/to/a	340
Contingencies	EUR/to/a	34
Construction Cost (net)	**EUR/to/a**	**374**
% eligible costs for grant	%	22,73%
Total Initial Investment	**kEUR**	**2 890**
INFLATION & ESCALATION RATES		
Inflation	% pa	2,00%
Escalation rate utilities	% pa	2,00%
Escalation rate personal	% pa	2,00%
Discount Factor	% pa	8,50%
TIME SCHEDULE (semi-annual)		
Price Basis for Cost Assumptions	Year	01.01.2012
Start of Construction	Date	01.07.2012
Construction Period	onths (shortest period 6 mo)	6
Start of Operation	Date	01.01.2013
Operation Period	Years	20
TIMELINE FOR BUSINESS PLAN		
Start Date Timeline	Date	01.01.2012

HTC Plant for compost works (best guess)

Input Data

All Figures in EUR unless otherwise stated — No. of Errors 0

Base Case

1

	POSITIONS RELEVANT TO INCOME ACCOUNT		
Feedstock	Acceptance of sludge	to/a	0,00
	Acceptance of leftovers	to/a	2 500,00
	Acceptance horse dung	to/a	5 000,00
	Acceptance wooden material	to/a	0,00
	Acceptance grass & foliage	to/a	2 500,00
	Acceptance Educt 1	to/a	0,00
	Acceptance Educt 2	to/a	0,00
Products	**HTC-coal**	No = 0/Yes =1	1
	HTC-coal (sludge)	to/a	0,00
	HTC-coal (leftovers)	to/a	581,53
	HTC-coal (horse dung)	to/a	1 123,61
	HTC-coal (wooden material)	to/a	0,00
	HTC-coal (grass & foliage)	to/a	604,42
	HTC-coal (educt 1)	to/a	0,00
	HTC-coal (educt 2)	to/a	0,00
	HTC-process water	No = 0/Yes =1	0
	HTC-process water (sludge)	to/a	0,00
	HTC-process water (leftovers)	to/a	0,00
	HTC-process water (horse dung)	to/a	0,00
	HTC-process water (wooden material)	to/a	0,00
	HTC-process water (grass & foliage)	to/a	0,00
	HTC-process water (educt 1)	to/a	0,00
	HTC-process water (educt 2)	to/a	0,00
others	**Heat (export)**	No = 0/Yes =1	1
	Heat (export)	MWh/a	3 659,31
	CO2-Certificates	No = 0/Yes =1	1
	CO2-Certificates	to/a	3 387,35
	Other Revenues	No = 0/Yes =1	0
	Revenue position 1	to/a	0,00
	Revenue position 2	to/a	0,00
	Revenue position 3	to/a	0,00
	Revenue position 4	to/a	0,00

HTC Plant for compost works (best guess)

Input Data

All Figures in EUR unless otherwise stated No. of Errors 0

Base Case

1

SALES PRICE ASSUMPTIONS		
Acceptance of sludge	EUR/to	35,00
Acceptance of leftovers	EUR/to	40,00
Acceptance horse dung	EUR/to	37,00
Acceptance wooden material	EUR/to	25,00
Acceptance grass & foliage	EUR/to	34,00
Acceptance Educt 1	EUR/to	0,00
Acceptance Educt 2	EUR/to	0,00
HTC-coal (sludge)	EUR/to	250,00
HTC-coal (leftovers)	EUR/to	250,00
HTC-coal (horse dung)	EUR/to	250,00
HTC-coal (wooden material)	EUR/to	250,00
HTC-coal (grass & foliage)	EUR/to	250,00
HTC-coal (educt 1)	EUR/to	250,00
HTC-coal (educt 2)	EUR/to	250,00
HTC-process water (sludge)	EUR/to	1,00
HTC-process water (leftovers)	EUR/to	1,00
HTC-process water (horse dung)	EUR/to	1,00
HTC-process water (wooden material)	EUR/to	1,00
HTC-process water (grass & foliage)	EUR/to	1,00
HTC-process water (educt 1)	EUR/to	1,00
HTC-process water (educt 2)	EUR/to	1,00
Heat (export)	EUR/MWh	22,00
CO2-Certificates	EUR/to	6,00
Revenue position 1	EUR/to	1,00
Revenue position 2	EUR/to	1,00
Revenue position 3	EUR/to	1,00
Revenue position 4	EUR/to	1,00

HTC Plant for compost works (best guess)

Input Data

All Figures in EUR unless otherwise stated No. of Errors 0

Base Case

1

OPERATING COSTS		
Operator/Management		
Operator 1	h/a	2 080,00
hourly rate operator 1	EUR/h	20,00
Operator 2	h/a	2 080,00
hourly rate operator 2	EUR/h	25,00
Management	h/a	208,00
hourly rate management	EUR/h	55,00
Operator/Management costs total per year	**EUR/a**	**105 040**
Utilities consumption		
Gas	kWh/a	0,00
Biomass	to/a	1 121,21
Electricity	kWh/a	750 000
Fresh water	m³/a	4 500
Waste water	m³/a	7 921,40
Chemicals	kg/a	200
Utilities Costs		
Gas	EUR/kWh	0,04
Biomass	EUR/to	100,00
Electricity	EUR/kWh	0,13
Fresh water	EUR/m³	1,50
Waste water	EUR/m³	3,50
Chemicals	EUR/kg	50,00
Total utilities consumption cost per year	**EUR/a**	254 096,12
Operation (external)		
Feedstock preparation (external; e.g. shredde	EUR/a	10 000,00
Maintenance	EUR/a	74 800,00
Miscellaneous 2	EUR/a	0,00
Total external operational costs per year	**EUR/a**	**84 800,00**
Land lease	EUR/a	15 000,00
Insurance	EUR/a	37 400,00
Contingencies	EUR/a	22 196,81
Operational Expenditure (OPEX) per year	**EUR/a**	**518 533**
WORKING CAPITAL		
Accounts Receivable	Days	30
Accounts Payable	Days	30

HTC Plant for compost works (best guess)

Input Data

All Figures in EUR unless otherwise stated No. of Errors 0

Base Case

1

DEPRECIATION & AMORTIZATION		
Components (Depreciation 20 Years)	Years	20
Components (Depreciation 10 Years)	Years	10
Components (Depreciation 5 Years)	Years	5
Components (Depreciation 1 Years)	Years	1
Start Depreciation (Depreciation 20 Years)	Date	01.01.2013
Start Depreciation (Depreciation 10 Years)	Date	01.01.2013
Start Depreciation (Depreciation 5 Years)	Date	01.01.2013
Start Depreciation (Depreciation 1 Years)	Date	01.01.2013
Components (Depreciation 20 Years)	%	70,00%
Components (Depreciation 10 Years)	%	30,00%
Components (Depreciation 5 Years)	%	0,00%
Components (Depreciation 1 Years)	%	0,00%
	Check	*0*
TAXES		
Corp. Income Tax	%	25,00%
Reserve Accounts		
Interest on Reserve Accounts	% pa	1,20%
Funding		
Equity	%	25%
Repayment of Equity	No = 0/Yes =1	1
Repayment of Bullet in operating Year	Date	01.01.2012
Long term loan	%	75%
Interest on Loan	%	4%
Repayment of loan (start)	Date	01.01.2014
REINVESTMENT RESERVE		
	% of Investment Volume	1,00%
Profit Distribution		
Share on free cash after tax and financing	%	75%
Profit Distribution	No = 0/Yes =1	1

HTC Plant for compost works (best guess)

Output

All Figures in EUR unless otherwise stated

Base Case

	Unit	Total	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Construction	flags	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operation	flags	20	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Operating Year	counter	20	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	0	0	0	0	0	0	0	0	0	0
PROFIT & LOSS ACCOUNT																																	
Revenue from Feedstock Acceptance	kEUR	7 492,50	92,50	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Revenue from HTC-coal	kEUR	11 547,77	0,00	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	577,39	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Revenue from HTC-process water	kEUR	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Revenue from other positions	kEUR	2 016,58	0,00	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	100,83	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
TOTAL TURNOVER	kEUR	21 057	93	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	0	0	0	0	0	0	0	0	0	0
Operator/Management costs total per year	kEUR	-2 643,07	-26,52	-107,68	-109,83	-112,03	-114,27	-116,56	-118,89	-121,27	-123,70	-126,17	-128,70	-131,27	-133,90	-136,58	-139,31	-142,10	-144,94	-147,85	-150,80	-153,82	-156,90	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total utilities consumption cost per year	kEUR	-6 329,55	0,00	-260,47	-265,68	-270,99	-276,42	-281,96	-287,60	-293,35	-299,22	-305,22	-311,32	-317,55	-323,91	-330,39	-337,00	-343,74	-350,63	-357,65	-364,80	-372,10	-379,55	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total external operational costs per year	kEUR	-2 112,37	0,00	-86,93	-88,67	-90,44	-92,25	-94,10	-95,98	-97,90	-99,86	-101,86	-103,90	-105,98	-108,10	-110,26	-112,47	-114,72	-117,02	-119,36	-121,75	-124,18	-126,67	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Land lease	kEUR	-381,23	-7,57	-15,38	-15,68	-16,00	-16,32	-16,64	-16,98	-17,32	-17,66	-18,02	-18,38	-18,75	-19,12	-19,50	-19,89	-20,29	-20,70	-21,11	-21,54	-21,97	-22,41	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Insurance	kEUR	-931,64	0,00	-38,34	-39,11	-39,89	-40,69	-41,50	-42,33	-43,18	-44,04	-44,92	-45,82	-46,74	-47,68	-48,63	-49,60	-50,59	-51,61	-52,64	-53,69	-54,77	-55,87	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Contingencies	kEUR	-552,92	0,00	-22,75	-23,21	-23,67	-24,15	-24,63	-25,12	-25,63	-26,14	-26,66	-27,20	-27,74	-28,30	-28,86	-29,44	-30,03	-30,63	-31,24	-31,87	-32,50	-33,16	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Depreciation	kEUR	-2 890	0	-188	-188	-188	-188	-188	-188	-188	-188	-188	-188	-101	-101	-101	-101	-101	-101	-101	-101	-101	-101	0	0	0	0	0	0	0	0	0	0
EARNINGS BEFORE INTEREST & TAXES (EBIT)	kEUR	5 216	58	329	318	307	296	285	273	262	250	238	225	299	286	273	259	246	232	217	203	188	173	0	0	0	0	0	0	0	0	0	0
EBIT Margin			*63%*	*31%*	*30%*	*29%*	*28%*	*27%*	*26%*	*25%*	*24%*	*23%*	*21%*	*29%*	*27%*	*26%*	*25%*	*23%*	*22%*	*21%*	*19%*	*18%*	*16%*										
Interest on Loan	kEUR	-885	0	-82	-81	-77	-73	-68	-64	-60	-55	-51	-47	-42	-38	-34	-29	-25	-21	-16	-12	-8	-3	0	0	0	0	0	0	0	0	0	0
Interest on Reserve Accounts	kEUR	559	0	1	5	8	11	14	17	20	22	25	28	31	33	35	38	40	42	44	47	49	51	0	0	0	0	0	0	0	0	0	0
Result from Ordinary Operations	kEUR	4 890	58	248	242	238	234	230	226	222	217	212	206	287	281	275	268	261	253	245	237	229	220	0	0	0	0	0	0	0	0	0	0
Corporate Income Tax	kEUR	-541	-15	-62	-31	-29	-27	-26	-24	-22	-20	-18	-16	-36	-34	-31	-29	-27	-24	-22	-19	-17	-14	0	0	0	0	0	0	0	0	0	0
PROFIT / LOSS FOR THE YEAR (NIAT)	kEUR	4 349	44	186	211	209	207	205	202	200	197	194	190	252	248	243	239	234	229	224	218	212	206	0	0	0	0	0	0	0	0	0	0
	Check	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
CASH FLOW																																	
TOTAL TURNOVER	kEUR	21 057	93	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	1 048	0	0	0	0	0	0	0	0	0	0
Operating Expenditures	kEUR	-12 950,77	-34,10	-531,54	-542,17	-553,02	-564,09	-575,39	-586,90	-598,64	-610,62	-622,85	-635,31	-648,02	-661,00	-674,23	-687,72	-701,47	-715,52	-729,85	-744,45	-759,34	-774,55	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Change in Working Capital	kEUR	0	-10	-33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	22	0	0	0	0	0	0	0	0	0
CASH FLOW FROM OPERATIONS PRE TAX	kEUR	8 106	49	484	507	496	485	474	462	451	439	426	414	401	388	375	362	348	334	320	305	290	275	22	0	0	0	0	0	0	0	0	0
Income Taxes	kEUR	-541	-15	-62	-31	-29	-27	-26	-24	-22	-20	-18	-16	-36	-34	-31	-29	-27	-24	-22	-19	-17	-14	0	0	0	0	0	0	0	0	0	0
CASH FLOW FROM OPERATIONS AFTER TAX	kEUR	7 565	34	422	476	467	458	448	438	429	418	408	398	366	355	344	333	321	310	298	286	274	261	22	0	0	0	0	0	0	0	0	0
CASH FLOW FROM INVESTMENTS	kEUR	-2 890	-2 890	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paid in Share Capital	kEUR	2 890	2 890	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Repayment of Equity	kEUR	-723	0	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	0	0	0	0	0	0	0	0	0	0
CASH FLOW FROM FINANCING	kEUR	2 168	2 890	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	-36	0	0	0	0	0	0	0	0	0	0
CASH FLOW AFTER TAXES BEFORE DEBT SERVICE	kEUR	6 843	34	386	440	431	422	412	402	392	382	372	362	329	319	308	296	285	274	262	250	237	225	22	0	0	0	0	0	0	0	0	0
Repayment of Debt	kEUR	-2 167,50	0,00	0,00	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	-114,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Interest on Loan	kEUR	-885,42	0,00	-82,37	-81,28	-76,95	-72,61	-68,28	-63,94	-59,61	-55,27	-50,94	-46,60	-42,27	-37,93	-33,60	-29,26	-24,93	-20,59	-16,26	-11,92	-7,59	-3,25	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Interest on Reserve Accounts	kEUR	559	0	1	5	8	11	14	17	20	22	25	28	31	33	35	38	40	42	44	47	49	51	0	0	0	0	0	0	0	0	0	0
Change in Reinvestment Reserve	kEUR	0	0	-29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	0	0	0
FREE CASH FLOW AFTER TAXES AND FINANCING	kEUR	4 349	34	276	250	248	246	243	241	238	235	232	229	204	200	195	191	186	181	176	170	164	187	22	0	0	0	0	0	0	0	0	0
FREE CASH FLOW AFTER TAXES, FINANCING AND PROFIT DISTRIBUTION	kEUR	0	34	276	156	62	61	61	60	60	59	58	57	51	50	49	48	47	45	44	43	41	47	-1 408	0	0	0	0	0	0	0	0	0
CUMULATED FREE CASH FLOW AFTER TAXES, FINANCING AND PROFIT DISTRIBUTION	kEUR		34	310	467	529	590	651	711	771	829	887	945	996	1 046	1 094	1 142	1 189	1 234	1 278	1 320	1 362	1 408	0	0	0	0	0	0	0	0	0	0
	check																																
BALANCE SHEET																																	
Assets																																	
Fixed Assets	kEUR	26 010	2 890	2 702	2 514	2 326	2 139	1 951	1 763	1 575	1 387	1 199	1 012	910	809	708	607	506	405	303	202	101	0	0	0	0	0	0	0	0	0	0	0
Current Assets																																	
Receivables	kEUR	1 738	15	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	0	0	0	0	0	0	0	0	0	0
Cash in Hand & Bank Deposits	kEUR	49 314	34	310	560	808	1 053	1 297	1 538	1 776	2 011	2 243	2 472	2 676	2 876	3 071	3 262	3 448	3 629	3 805	3 976	4 140	4 327	0	0	0	0	0	0	0	0	0	0
Reinvestment Reserve	kEUR	549	0	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	0	0	0	0	0	0	0	0	0	0	0
Total Assets	kEUR	77 611	2 939	3 128	3 189	3 249	3 307	3 362	3 415	3 466	3 513	3 558	3 599	3 702	3 800	3 894	3 984	4 069	4 149	4 224	4 293	4 356	4 413	0	0	0	0	0	0	0	0	0	0
Liabilities																																	
Equity																																	
Paid-in Share Capital	kEUR		723	686	650	614	578	542	506	470	434	397	361	325	289	253	217	181	145	108	72	36	0	0	0	0	0	0	0	0	0	0	0
Drawn Debt	kEUR		2 168	2 168	2 053	1 939	1 825	1 711	1 597	1 483	1 369	1 255	1 141	1 027	913	799	684	570	456	342	228	114	0	0	0	0	0	0	0	0	0	0	0
Profit / Loss carried forward	kEUR		0	137	336	546	754	960	1 163	1 364	1 563	1 758	1 950	2 171	2 421	2 666	2 907	3 144	3 375	3 602	3 823	4 038	4 247	0	0	0	0	0	0	0	0	0	0
Profit / Loss for the Year	kEUR	2 187	44	92	105	104	103	102	101	99	98	96	95	125	123	121	119	116	114	111	108	105	102	0	0	0	0	0	0	0	0	0	0
Liabilities																																	
from trade payables	kEUR	1 072	6	44	45	46	47	48	48	49	50	51	52	54	55	56	57	58	59	60	61	63	64	0	0	0	0	0	0	0	0	0	0
Total Liabilities	kEUR	77 611	2 939	3 128	3 189	3 249	3 307	3 362	3 415	3 466	3 513	3 558	3 599	3 702	3 800	3 894	3 984	4 069	4 149	4 224	4 293	4 356	4 413	0	0	0	0	0	0	0	0	0	0
	Checksum	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

HTC Plant for compost works (best guess)

RATIOS

All Figures in EUR unless otherwise stated

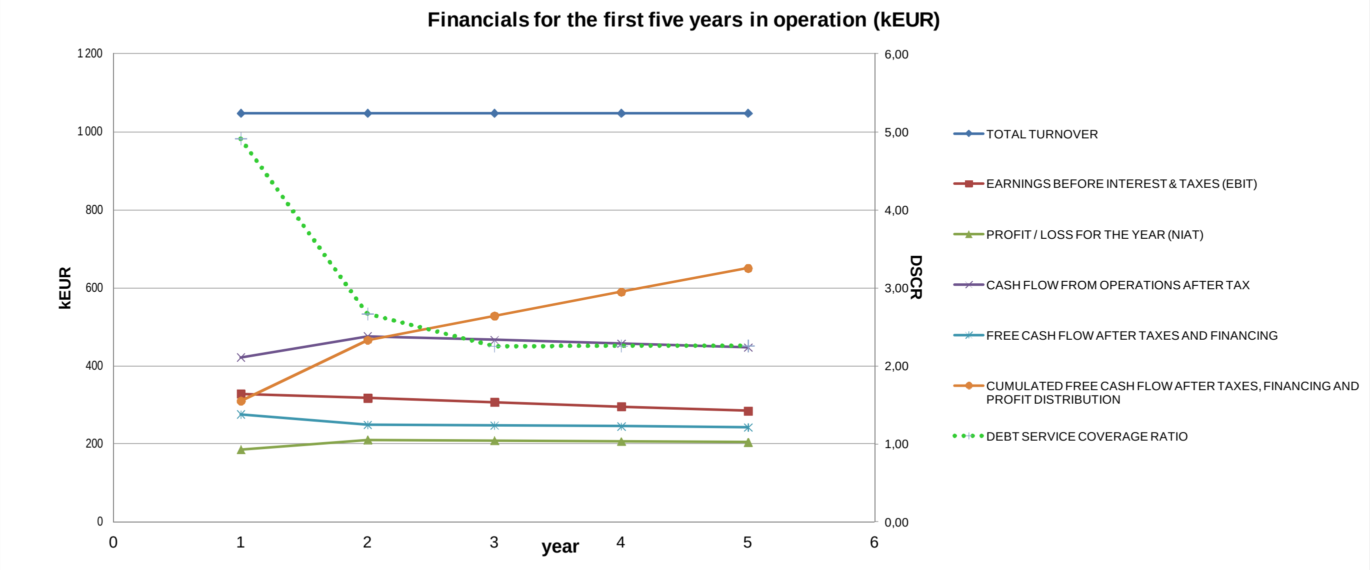
Base Case Errors: 0

Input Data		
Project Parameters		
Price Basis for Cost Assumptions	01.01.2012	Year
Start of Construction	01.07.2012	Date
Construction Period	6,00	Month
Start of Operation	01.01.2013	Date
Operation Period	20,00	Years
Feedstock Processing Capacity	10 000,00	to/a
Feedstock Composition		
Leftovers	2 500,00	to/a
Horse Dung	5 000,00	to/a
Grass & Foilage	2 500,00	to/a
Products		
HTC-coal (leftovers)	581,53	to/a
HTC-coal (horse dung)	1 123,61	to/a
HTC-coal (grass & foliage)	604,42	to/a
HTC-process water (leftovers)	0,00	to/a
HTC-process water (horse dung)	0,00	to/a
HTC-process water (grass & foliage)	0,00	to/a
Heat (export)	3 659,31	MWh/a
CO2-Certificates	3 387,35	to/a
Utility Consumption		
Gas	0,00	kWh/a
Biomass	1 121,21	to/a
Electricity	750 000,00	kWh/a
Fresh water	4 500,00	m³/a
Waste water	7 921,40	m³/a
Chemicals	200,00	kg/a

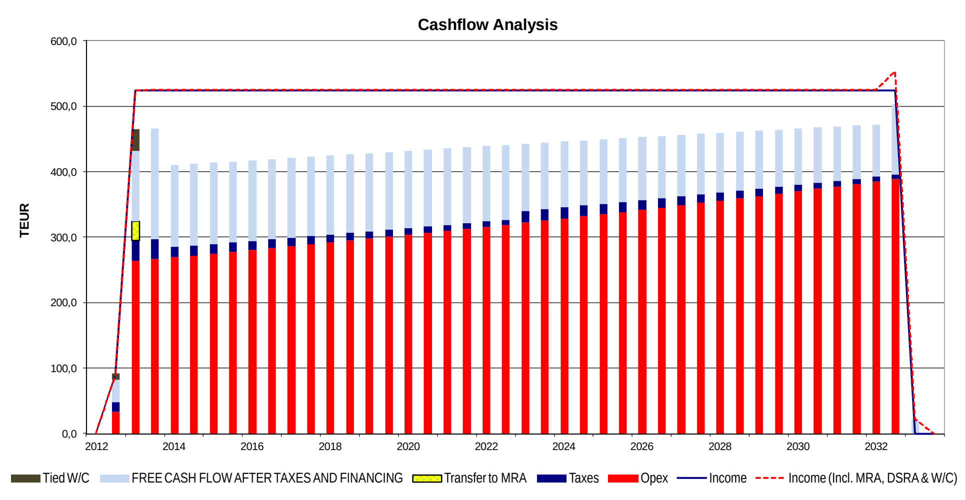
Financial Input Parameters		
Inflation	2,00%	pa
Escalation rate utilities	2,00%	pa
Escalation rate personal	2,00%	pa
Discount Factor	8,50%	pa
Components (Depreciation 20 Years)	70,0%	
Components (Depreciation 10 Years)	30,0%	
Components (Depreciation 5 Years)	0,0%	
Components (Depreciation 1 Years)	0,0%	
Corp. Income Tax	25,0%	
Total Initial Investment	2 890,0	kEUR
Operator/Management costs total per year	105 040,0	EUR/a
Total utilities consumption cost per year	254 096,1	EUR/a
Total external operational costs per year	84 800,0	EUR/a
Operational Expenditure (OPEX) per year	518 532,9	EUR/a

Financial Output Parameters	**Base Case**	
Financials after taxes based on capital (equity + debt):		
IRR	14,04%	
NPV	1 008	kEUR
Pay back period in years	10	years
Average DSCR	2,24x	
Minimum DSCR	1,92x	
Break Even HTC-Coal Price	191,23	EUR

Financials for the first five years in operation (kEUR)	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**
TOTAL TURNOVER	1 048	1 048	1 048	1 048	1 048
EARNINGS BEFORE INTEREST & TAXES (EBIT)	329	318	307	296	285
PROFIT / LOSS FOR THE YEAR (NIAT)	186	211	209	207	205
CASH FLOW FROM OPERATIONS AFTER TAX	422	476	467	458	448
FREE CASH FLOW AFTER TAXES AND FINANCING	276	250	248	246	243
CUMULATED FREE CASH FLOW AFTER TAXES, FINANCING AND PROFIT DISTRIBU	310	467	529	590	651
DEBT SERVICE COVERAGE RATIO	4,91	2,67	2,25	2,26	2,26

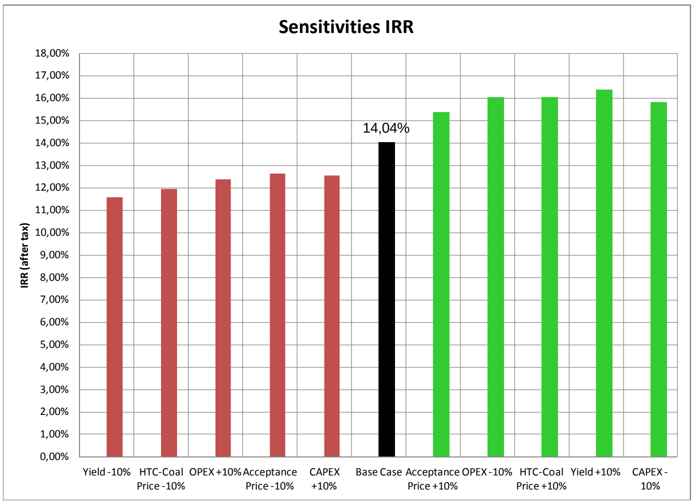


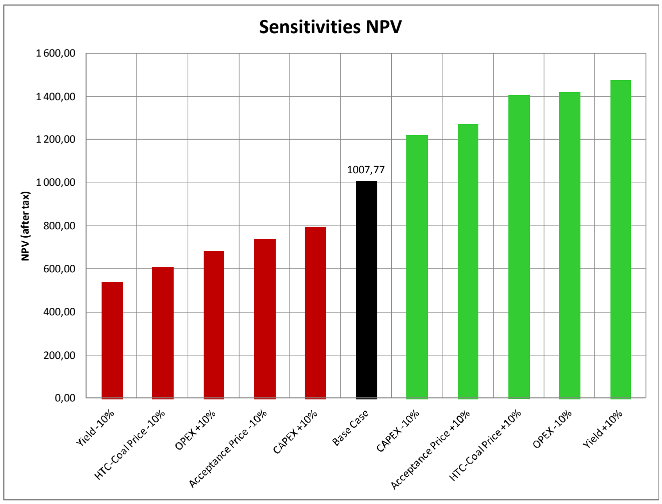
Calculation of semi-annual Returns		
Return on Project		**nominal**
Cashflow before Taxes, before Financing	% p.a.	15,60%
Cashflow after Taxes, before Financing	% p.a.	14,04%
Pay Back Period		
Pay Back Period	Years	10,00
Net Present Value (NPV)		
Discount Factor	% p.a.	8,50%
NPV (after tax)	kEUR	1 008

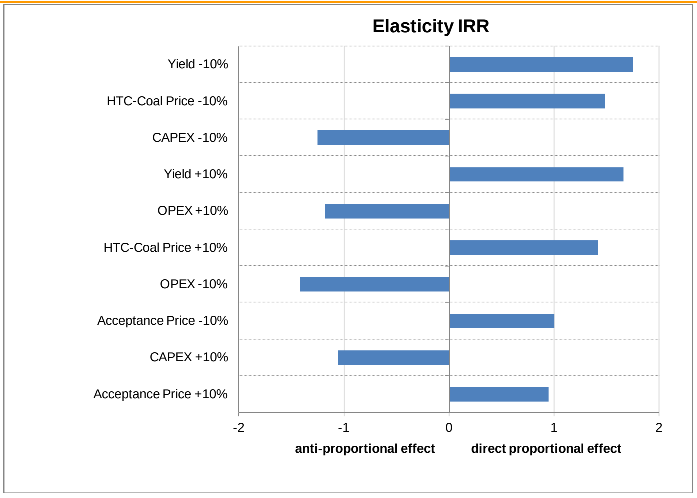


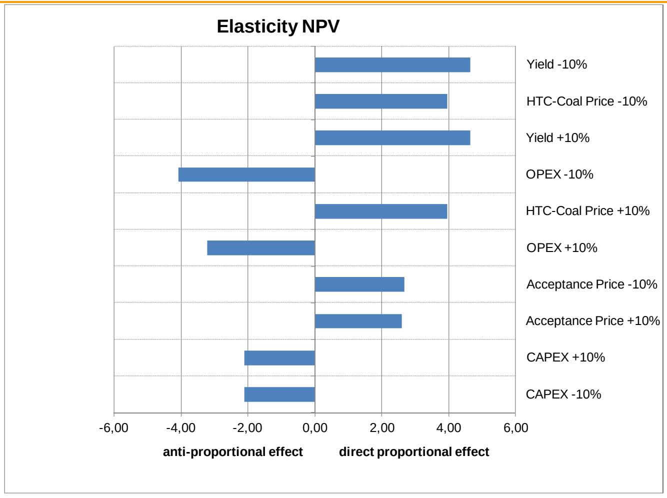
SENSITIVITIES

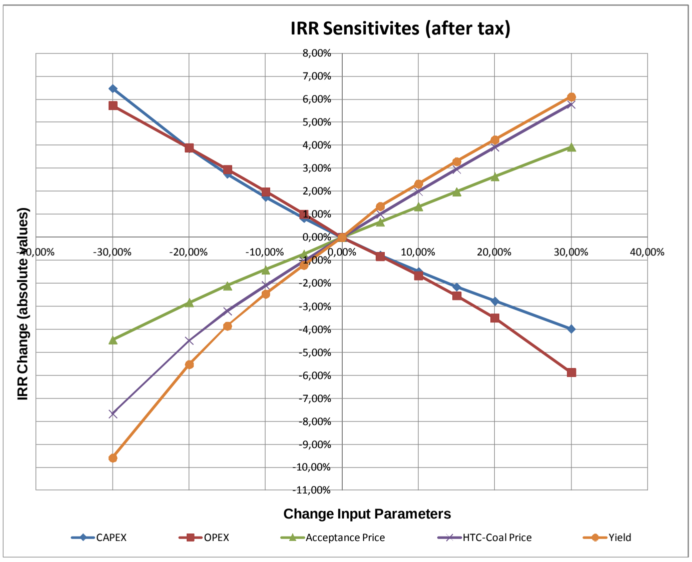
Sensitivities	Input Change	IRR Base Case (after tax)	IRR change (after tax)	rel. Change	IRR Elasticity	NPV Base Case (k€ after tax)	NPV change (k€ after tax)	rel. Change	NPV Elasticity
CAPEX	-10,0%	**14,04%**	15,79%	12,50%	-1,25	1 007,77	1220,4	21,10%	-2,11
	+10,0%		12,55%	-10,59%	-1,06		795,2	-21,10%	-2,11
OPEX	-10,0%		16,03%	14,19%	-1,42		1419,9	40,89%	-4,09
	+10,0%		12,38%	-11,79%	-1,18		682,9	-32,23%	-3,22
Acceptance Price	-10,0%		12,63%	-10,02%	1,00		738,0	-26,77%	2,68
	+10,0%		15,37%	9,49%	0,95		1269,4	25,96%	2,60
HTC-Coal Price	-10,0%		11,96%	-14,81%	1,48		609,7	-39,50%	3,95
	+10,0%		16,02%	14,17%	1,42		1405,7	39,49%	3,95
HTC-Process Water Price	-10,0%		14,04%	0,00%	0,00		1007,8	0,00%	0,00
Price	+10,0%		14,04%	0,00%	0,00		1007,8	0,00%	0,00
Yield	-10,0%		11,58%	-17,51%	1,75		539,3	-46,49%	4,65
	+10,0%		16,36%	16,59%	1,66		1475,2	46,38%	4,64
0			14,04%	0,00%	0,00		1007,8	0,00%	0,00

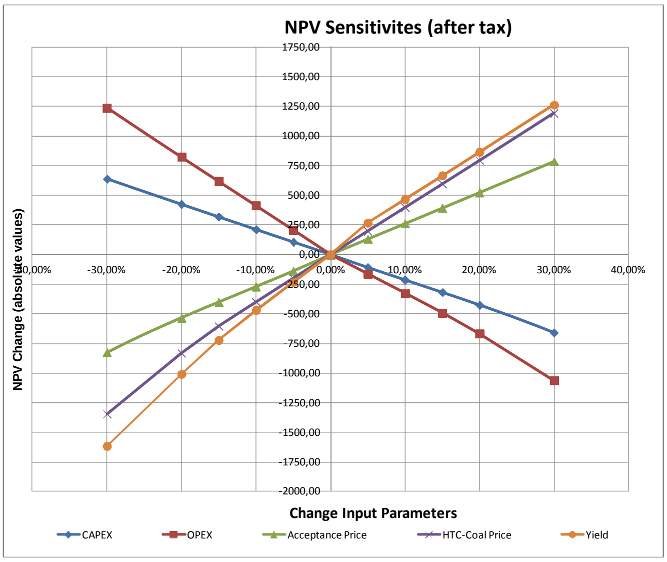












ANNEX 4

HTC Plant for compost works (worst scenario)

Input Data

All Figures in EUR unless otherwise stated　　No. of Errors 0

Base Case

1

PROJECT IDENTIFICATION		
Project Name		**Plant for compost works (worst scenario)**
Project Location		Lower Austria
Project Country		Austria
Name of Project Company		Compost Test Company
Legal Form of Project Company		GmbH
Country of Origin		Austria
MODEL SETTINGS		
Language Selection	1=Deutsch; 2=English	2
Business Plan Currency		EUR
Additional Reporting-Currency		none
Installed Plant Capacity		No = 0 / Yes = 1
Feedstock Processing Capacity	**10000,0 to/a**	**1**
PURCHASE PARAMETERS		
CAPEX	EUR/to/a	340
Contingencies	EUR/to/a	34
Construction Cost (net)	**EUR/to/a**	**374**
% eligible costs for grant	%	0,00%
Total Initial Investment	**kEUR**	**3 740**
INFLATION & ESCALATION RATES		
Inflation	% pa	2,00%
Escalation rate utilities	% pa	2,00%
Escalation rate personal	% pa	2,00%
Discount Factor	% pa	8,50%
TIME SCHEDULE (semi-annual)		
Price Basis for Cost Assumptions	Year	01.01.2012
Start of Construction	Date	01.07.2012
Construction Period	onths (shortest period 6 mo)	6
Start of Operation	Date	01.01.2013
Operation Period	Years	20
TIMELINE FOR BUSINESS PLAN		
Start Date Timeline	Date	01.01.2012

HTC Plant for compost works (worst scenario)

Input Data

All Figures in EUR unless otherwise stated

No. of Errors 0

Base Case

1

POSITIONS RELEVANT TO INCOME ACCOUNT			
Feedstock	Acceptance of sludge	to/a	0,00
	Acceptance of leftovers	to/a	2 500,00
	Acceptance horse dung	to/a	5 000,00
	Acceptance wooden material	to/a	0,00
	Acceptance grass & foliage	to/a	2 500,00
	Acceptance Educt 1	to/a	0,00
	Acceptance Educt 2	to/a	0,00
Products	**HTC-coal**	No = 0/Yes =1	1
	HTC-coal (sludge)	to/a	0,00
	HTC-coal (leftovers)	to/a	581,53
	HTC-coal (horse dung)	to/a	1 123,61
	HTC-coal (wooden material)	to/a	0,00
	HTC-coal (grass & foliage)	to/a	604,42
	HTC-coal (educt 1)	to/a	0,00
	HTC-coal (educt 2)	to/a	0,00
	HTC-process water	No = 0/Yes =1	0
	HTC-process water (sludge)	to/a	0,00
	HTC-process water (leftovers)	to/a	0,00
	HTC-process water (horse dung)	to/a	0,00
	HTC-process water (wooden material)	to/a	0,00
	HTC-process water (grass & foliage)	to/a	0,00
	HTC-process water (educt 1)	to/a	0,00
	HTC-process water (educt 2)	to/a	0,00
others	**Heat (export)**	No = 0/Yes =1	1
	Heat (export)	MWh/a	3 659,31
	CO2-Certificates	No = 0/Yes =1	0
	CO2-Certificates	to/a	0,00
	Other Revenues	No = 0/Yes =1	0
	Revenue position 1	to/a	0,00
	Revenue position 2	to/a	0,00
	Revenue position 3	to/a	0,00
	Revenue position 4	to/a	0,00

HTC Plant for compost works (worst scenario)

Input Data

All Figures in EUR unless otherwise stated No. of Errors 0

Base Case

1

SALES PRICE ASSUMPTIONS		
Acceptance of sludge	EUR/to	35,00
Acceptance of leftovers	EUR/to	40,00
Acceptance horse dung	EUR/to	37,00
Acceptance wooden material	EUR/to	25,00
Acceptance grass & foliage	EUR/to	34,00
Acceptance Educt 1	EUR/to	0,00
Acceptance Educt 2	EUR/to	0,00
HTC-coal (sludge)	EUR/to	193,00
HTC-coal (leftovers)	EUR/to	193,00
HTC-coal (horse dung)	EUR/to	193,00
HTC-coal (wooden material)	EUR/to	193,00
HTC-coal (grass & foliage)	EUR/to	193,00
HTC-coal (educt 1)	EUR/to	193,00
HTC-coal (educt 2)	EUR/to	193,00
HTC-process water (sludge)	EUR/to	1,00
HTC-process water (leftovers)	EUR/to	1,00
HTC-process water (horse dung)	EUR/to	1,00
HTC-process water (wooden material)	EUR/to	1,00
HTC-process water (grass & foliage)	EUR/to	1,00
HTC-process water (educt 1)	EUR/to	1,00
HTC-process water (educt 2)	EUR/to	1,00
Heat (export)	EUR/MWh	22,00
CO2-Certificates	EUR/to	6,00
Revenue position 1	EUR/to	1,00
Revenue position 2	EUR/to	1,00
Revenue position 3	EUR/to	1,00
Revenue position 4	EUR/to	1,00

HTC Plant for compost works (worst scenario)

Input Data

All Figures in EUR unless otherwise stated No. of Errors 0

Base Case

		1
OPERATING COSTS		
Operator/Management		
Operator 1	h/a	2 080,00
hourly rate operator 1	EUR/h	20,00
Operator 2	h/a	2 080,00
hourly rate operator 2	EUR/h	25,00
Management	h/a	208,00
hourly rate management	EUR/h	55,00
Operator/Management costs total per year	**EUR/a**	**105 040**
Utilities consumption		
Gas	kWh/a	0,00
Biomass	to/a	1 121,21
Electricity	kWh/a	750 000
Fresh water	m³/a	4 500
Waste water	m³/a	7 921,40
Chemicals	kg/a	200
Utilities Costs		
Gas	EUR/kWh	0,04
Biomass	EUR/to	100,00
Electricity	EUR/kWh	0,13
Fresh water	EUR/m³	1,50
Waste water	EUR/m³	3,50
Chemicals	EUR/kg	50,00
Total utilities consumption cost per year	**EUR/a**	254 096,12
Operation (external)		
Feedstock preparation (external; e.g. shredde	EUR/a	10 000,00
Maintenance	EUR/a	74 800,00
Miscellaneous 2	EUR/a	0,00
Total external operational costs per year	**EUR/a**	**84 800,00**
Land lease	EUR/a	15 000,00
Insurance	EUR/a	37 400,00
Contingencies	EUR/a	22 196,81
Operational Expenditure (OPEX) per year	**EUR/a**	**518 533**
WORKING CAPITAL		
Accounts Receivable	Days	30
Accounts Payable	Days	30

HTC Plant for compost works (worst scenario)

Input Data

All Figures in EUR unless otherwise stated No. of Errors 0

Base Case

1

DEPRECIATION & AMORTIZATION		
Components (Depreciation 20 Years)	Years	20
Components (Depreciation 10 Years)	Years	10
Components (Depreciation 5 Years)	Years	5
Components (Depreciation 1 Years)	Years	1
Start Depreciation (Depreciation 20 Years)	Date	01.01.2013
Start Depreciation (Depreciation 10 Years)	Date	01.01.2013
Start Depreciation (Depreciation 5 Years)	Date	01.01.2013
Start Depreciation (Depreciation 1 Years)	Date	01.01.2013
Components (Depreciation 20 Years)	%	70,00%
Components (Depreciation 10 Years)	%	30,00%
Components (Depreciation 5 Years)	%	0,00%
Components (Depreciation 1 Years)	%	0,00%
	Check	*0*
TAXES		
Corp. Income Tax	%	25,00%
Reserve Accounts		
Interest on Reserve Accounts	% pa	1,20%
Funding		
Equity	%	25%
Repayment of Equity	No = 0/Yes =1	1
Repayment of Bullet in operating Year	Date	01.01.2012
Long term loan	%	75%
Interest on Loan	%	4%
Repayment of loan (start)	Date	01.01.2014
REINVESTMENT RESERVE		
	% of Investment Volume	1,00%
Profit Distribution		
Share on free cash after tax and financing	%	75%
Profit Distribution	No = 0/Yes =1	1

HTC Plant for compost works (worst scenario)

Output

All Figures in EUR unless otherwise stated

Base Case

	Unit	Total	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042
Construction	flags	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operation	flags	20	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Operating Year	counter	20	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	0	0	0	0	0	0	0	0	0	0
PROFIT & LOSS ACCOUNT																																	
Revenue from Feedstock Acceptance	kEUR	7 492,50	92,50	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	370,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Revenue from HTC-coal	kEUR	8 914,88	0,00	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	445,74	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Revenue from HTC-process water	kEUR	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Revenue from other positions	kEUR	1 610,09	0,00	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	80,50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
TOTAL TURNOVER	kEUR	18 017	93	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	0	0	0	0	0	0	0	0	0	0
Operator/Management costs total per year	kEUR	-2 643,07	-26,52	-107,68	-109,83	-112,03	-114,27	-116,56	-118,89	-121,27	-123,70	-126,17	-128,70	-131,27	-133,90	-136,58	-139,31	-142,10	-144,94	-147,85	-150,80	-153,82	-156,90	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total utilities consumption cost per year	kEUR	-6 329,55	0,00	-260,47	-265,68	-270,99	-276,42	-281,96	-287,60	-293,35	-299,22	-305,22	-311,32	-317,55	-323,91	-330,39	-337,00	-343,74	-350,63	-357,65	-364,80	-372,10	-379,55	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Total external operational costs per year	kEUR	-2 112,37	0,00	-86,93	-88,67	-90,44	-92,25	-94,10	-95,98	-97,90	-99,86	-101,86	-103,90	-105,98	-108,10	-110,26	-112,47	-114,72	-117,02	-119,36	-121,75	-124,18	-126,67	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Land lease	kEUR	-381,23	-7,57	-15,38	-15,68	-16,00	-16,32	-16,64	-16,98	-17,32	-17,66	-18,02	-18,38	-18,75	-19,12	-19,50	-19,89	-20,29	-20,70	-21,11	-21,54	-21,97	-22,41	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Insurance	kEUR	-931,64	0,00	-38,34	-39,11	-39,89	-40,69	-41,50	-42,33	-43,18	-44,04	-44,92	-45,82	-46,74	-47,68	-48,63	-49,60	-50,59	-51,61	-52,64	-53,69	-54,77	-55,87	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Contingencies	kEUR	-552,92	0,00	-22,75	-23,21	-23,67	-24,15	-24,63	-25,12	-25,63	-26,14	-26,66	-27,20	-27,74	-28,30	-28,86	-29,44	-30,03	-30,63	-31,24	-31,87	-32,50	-33,16	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Depreciation	kEUR	-3 740	0	-243	-243	-243	-243	-243	-243	-243	-243	-243	-243	-131	-131	-131	-131	-131	-131	-131	-131	-131	-131	0	0	0	0	0	0	0	0	0	0
EARNINGS BEFORE INTEREST & TAXES (EBIT)	kEUR	1 327	58	122	111	100	89	78	66	55	43	30	18	117	104	91	78	64	50	35	21	6	-9	0	0	0	0	0	0	0	0	0	0
EBIT Margin			*63%*	*14%*	*12%*	*11%*	*10%*	*9%*	*7%*	*6%*	*5%*	*3%*	*2%*	*13%*	*12%*	*10%*	*9%*	*7%*	*6%*	*4%*	*2%*	*1%*	*-1%*										
Interest on Loan	kEUR	-1 146	0	-107	-105	-100	-94	-88	-83	-77	-72	-66	-60	-55	-49	-43	-38	-32	-27	-21	-15	-10	-4	0	0	0	0	0	0	0	0	0	0
Interest on Reserve Accounts	kEUR	105	0	1	3	4	4	5	5	6	6	6	7	7	7	7	7	6	6	6	5	5	4	0	0	0	0	0	0	0	0	0	0
Result from Ordinary Operations	kEUR	286	58	16	9	4	-1	-6	-11	-17	-23	-29	-36	69	62	54	46	38	29	20	11	1	-10	0	0	0	0	0	0	0	0	0	0
Corporate Income Tax	kEUR	-18	-15	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PROFIT / LOSS FOR THE YEAR (NIAT)	kEUR	267	44	12	9	4	-1	-6	-11	-17	-23	-29	-36	69	62	54	46	38	29	20	11	1	-10	0	0	0	0	0	0	0	0	0	0
	Check	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
CASH FLOW																																	
TOTAL TURNOVER	kEUR	18 017	93	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	896	0	0	0	0	0	0	0	0	0	0
Operating Expenditures	kEUR	-12 950,77	-34,10	-531,54	-542,17	-553,02	-564,09	-575,39	-586,90	-598,64	-610,62	-622,85	-635,31	-648,02	-661,00	-674,23	-687,72	-701,47	-715,52	-729,85	-744,45	-759,34	-774,55	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Change in Working Capital	kEUR	0	-10	-20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	10	0	0	0	0	0	0	0	0	0
CASH FLOW FROM OPERATIONS PRE TAX	kEUR	5 067	49	345	355	344	333	322	310	299	287	274	262	249	236	223	210	196	182	168	153	138	123	10	0	0	0	0	0	0	0	0	0
Income Taxes	kEUR	-18	-15	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CASH FLOW FROM OPERATIONS AFTER TAX	kEUR	5 048	34	341	355	344	333	322	310	299	287	274	262	249	236	223	210	196	182	168	153	138	123	10	0	0	0	0	0	0	0	0	0
CASH FLOW FROM INVESTMENTS	kEUR	-3 740	-3 740	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Paid in Share Capital	kEUR	3 740	3 740	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Repayment of Equity	kEUR	-935	0	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	0	0	0	0	0	0	0	0	0	0
CASH FLOW FROM FINANCING	kEUR	2 805	3 740	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	-47	0	0	0	0	0	0	0	0	0	0
CASH FLOW AFTER TAXES BEFORE DEBT SERVICE	kEUR	4 113	34	294	308	297	286	275	264	252	240	228	215	203	190	176	163	149	135	121	106	91	76	10	0	0	0	0	0	0	0	0	0
Repayment of Debt	kEUR	-2 805,00	0,00	0,00	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	-147,63	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Interest on Loan	kEUR	-1 145,84	0,00	-106,59	-105,19	-99,58	-93,97	-88,36	-82,75	-77,14	-71,53	-65,92	-60,31	-54,70	-49,09	-43,48	-37,87	-32,26	-26,65	-21,04	-15,43	-9,82	-4,21	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Interest on Reserve Accounts	kEUR	105	0	1	3	4	4	5	5	6	6	6	7	7	7	7	7	6	6	6	5	5	4	0	0	0	0	0	0	0	0	0	0
Change in Reinvestment Reserve	kEUR	0	0	-37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	0	0	0	0	0	0	0	0	0
FREE CASH FLOW AFTER TAXES AND FINANCING	kEUR	267	34	151	58	54	49	44	38	33	27	20	14	7	0	-8	-16	-24	-33	-42	-52	-62	-34	10	0	0	0	0	0	0	0	0	0
FREE CASH FLOW AFTER TAXES, FINANCING AND PROFIT DISTRIBUTION	kEUR	0	34	151	37	13	49	44	38	33	27	20	14	7	0	-8	-16	-24	-33	-42	-52	-62	-34	-196	0	0	0	0	0	0	0	0	0
CUMULATED FREE CASH FLOW AFTER TAXES, FINANCING AND PROFIT DISTRIBUTION	kEUR		34	185	222	235	284	328	366	399	426	446	460	467	467	459	443	419	386	344	292	230	196	0	0	0	0	0	0	0	0	0	0
	check																																
BALANCE SHEET																																	
Assets																																	
Fixed Assets	kEUR	33 660	3 740	3 497	3 254	3 011	2 768	2 525	2 281	2 038	1 795	1 552	1 309	1 178	1 047	916	785	655	524	393	262	131	0	0	0	0	0	0	0	0	0	0	0
Current Assets																																	
Receivables	kEUR	1 488	15	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	0	0	0	0	0	0	0	0	0	0
Cash in Hand & Bank Deposits	kEUR	8 223	34	185	243	297	346	390	428	461	488	508	522	529	529	521	505	480	447	405	354	292	258	0	0	0	0	0	0	0	0	0	0
Reinvestment Reserve	kEUR	711	0	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	0	0	0	0	0	0	0	0	0	0	0
Total Assets	kEUR	44 082	3 789	3 793	3 608	3 419	3 225	3 025	2 821	2 610	2 394	2 171	1 942	1 818	1 687	1 548	1 401	1 246	1 082	909	727	534	331	0	0	0	0	0	0	0	0	0	0
Liabilities																																	
Equity																																	
Paid-in Share Capital	kEUR		935	888	842	795	748	701	655	608	561	514	468	421	374	327	281	234	187	140	94	47	0	0	0	0	0	0	0	0	0	0	0
Drawn Debt	kEUR		2 805	2 805	2 657	2 510	2 362	2 214	2 067	1 919	1 772	1 624	1 476	1 329	1 181	1 033	886	738	591	443	295	148	0	0	0	0	0	0	0	0	0	0	0
Profit / Loss carried forward	kEUR		0	51	61	67	69	66	57	43	23	-3	-35	-19	47	105	156	198	232	257	272	278	273	0	0	0	0	0	0	0	0	0	0
Profit / Loss for the Year	kEUR	138	44	5	4	1	-1	-4	-6	-9	-12	-15	-19	34	30	26	22	18	14	9	4	-1	-6	0	0	0	0	0	0	0	0	0	0
Liabilities																																	
from trade payables	kEUR	1 072	6	44	45	46	47	48	48	49	50	51	52	54	55	56	57	58	59	60	61	63	64	0	0	0	0	0	0	0	0	0	0
Total Liabilities	kEUR	44 082	3 789	3 793	3 608	3 419	3 225	3 025	2 821	2 610	2 394	2 171	1 942	1 818	1 687	1 548	1 401	1 246	1 082	909	727	534	331	0	0	0	0	0	0	0	0	0	0
	Checksum	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

HTC Plant for compost works (worst scenario)

RATIOS

All Figures in EUR unless otherwise stated

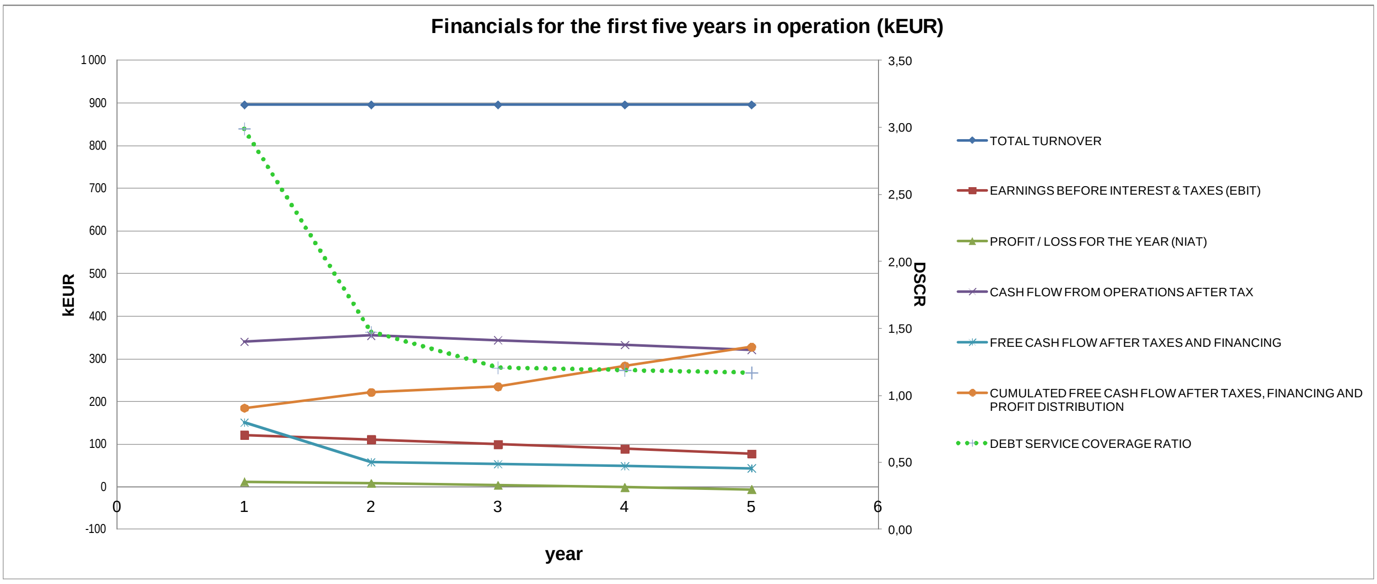
Base Case Errors: 0

Input Data		
Project Parameters		
Price Basis for Cost Assumptions	01.01.2012	Year
Start of Construction	01.07.2012	Date
Construction Period	6,00	Month
Start of Operation	01.01.2013	Date
Operation Period	20,00	Years
Feedstock Processing Capacity	10 000,00	to/a
Feedstock Composition		
Leftovers	2 500,00	to/a
Horse Dung	5 000,00	to/a
Grass & Foilage	2 500,00	to/a
Products		
HTC-coal (leftovers)	581,53	to/a
HTC-coal (horse dung)	1 123,61	to/a
HTC-coal (grass & foliage)	604,42	to/a
HTC-process water (leftovers)	0,00	to/a
HTC-process water (horse dung)	0,00	to/a
HTC-process water (grass & foliage)	0,00	to/a
Heat (export)	3 659,31	MWh/a
CO2-Certificates	0,00	to/a
Utility Consumption		
Gas	0,00	kWh/a
Biomass	1 121,21	to/a
Electricity	750 000,00	kWh/a
Fresh water	4 500,00	m³/a
Waste water	7 921,40	m³/a
Chemicals	200,00	kg/a

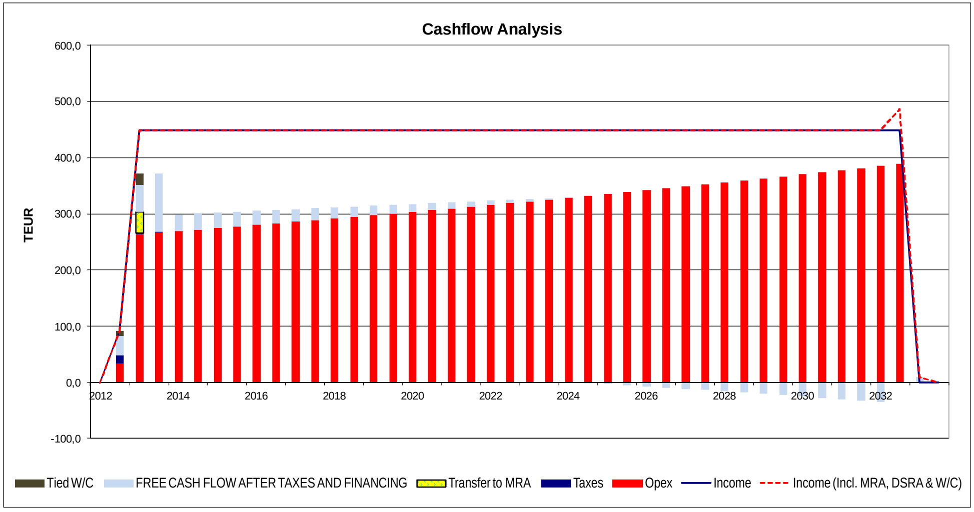
Financial Input Parameters		
Inflation	2,00%	pa
Escalation rate utilities	2,00%	pa
Escalation rate personal	2,00%	pa
Discount Factor	8,50%	pa
Components (Depreciation 20 Years)	70,0%	
Components (Depreciation 10 Years)	30,0%	
Components (Depreciation 5 Years)	0,0%	
Components (Depreciation 1 Years)	0,0%	
Corp. Income Tax	25,0%	
Total Initial Investment	3 740,0	kEUR
Operator/Management costs total per year	105 040,0	EUR/a
Total utilities consumption cost per year	254 096,1	EUR/a
Total external operational costs per year	84 800,0	EUR/a
Operational Expenditure (OPEX) per year	518 532,9	EUR/a

Financial Output Parameters	**Base Case**	
Financials after taxes based on capital (equity + debt):		
IRR	3,81%	
NPV	-943	kEUR
Pay back period in years	no Value	years
Average DSCR	1,04x	
Minimum DSCR	0,50x	
Break Even HTC-Coal Price	238,64	EUR

Financials for the first five years in operation (kEUR)	**year 1**	**year 2**	**year 3**	**year 4**	**year 5**
TOTAL TURNOVER	896	896	896	896	896
EARNINGS BEFORE INTEREST & TAXES (EBIT)	122	111	100	89	78
PROFIT / LOSS FOR THE YEAR (NIAT)	12	9	4	-1	-6
CASH FLOW FROM OPERATIONS AFTER TAX	341	355	344	333	322
FREE CASH FLOW AFTER TAXES AND FINANCING	151	58	54	49	44
CUMULATED FREE CASH FLOW AFTER TAXES, FINANCING AND PROFIT DISTRIBU	185	222	235	284	328
DEBT SERVICE COVERAGE RATIO	2,99	1,47	1,21	1,19	1,17

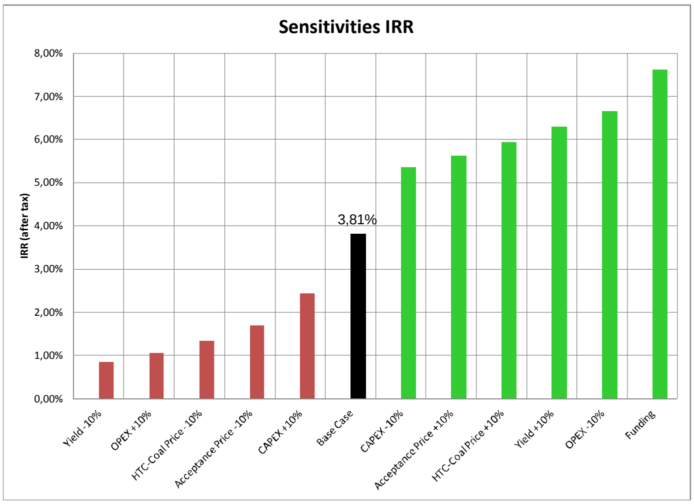


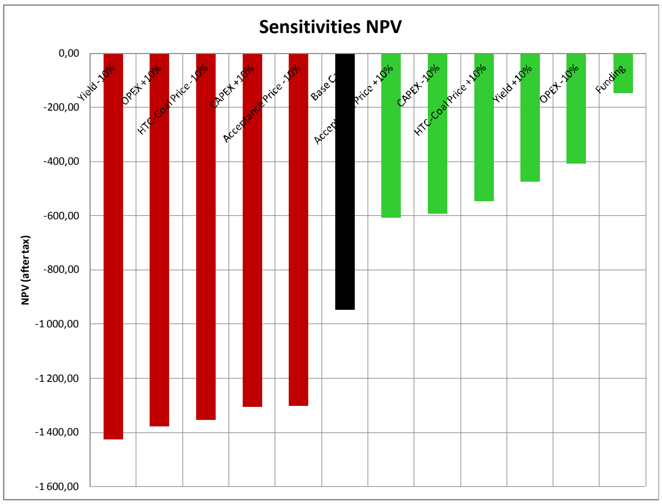
Calculation of semi-annual Returns		
Return on Project		**nominal**
Cashflow before Taxes, before Financing	% p.a.	3,88%
Cashflow after Taxes, before Financing	% p.a.	3,81%
Pay Back Period		
Pay Back Period	Years	no Value
Net Present Value (NPV)		
Discount Factor	% p.a.	8,50%
NPV (after tax)	kEUR	-943

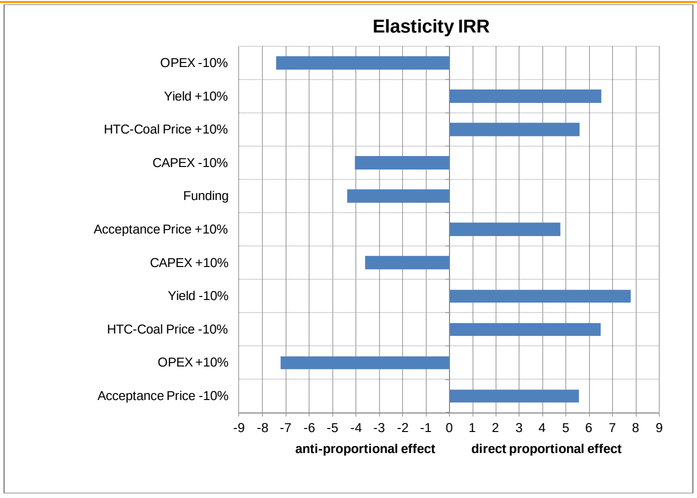


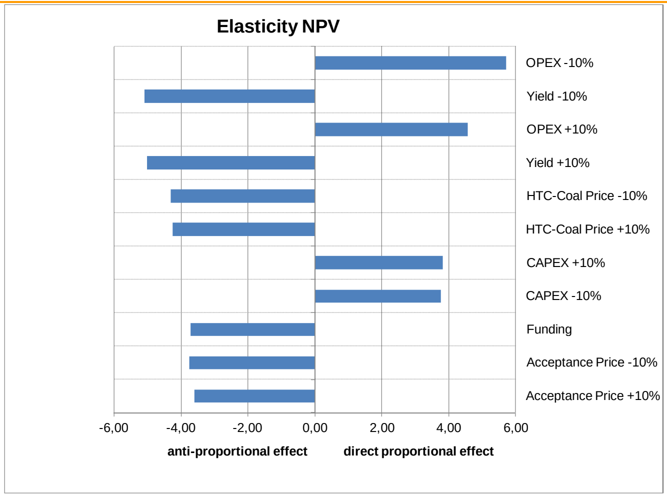
SENSITIVITIES

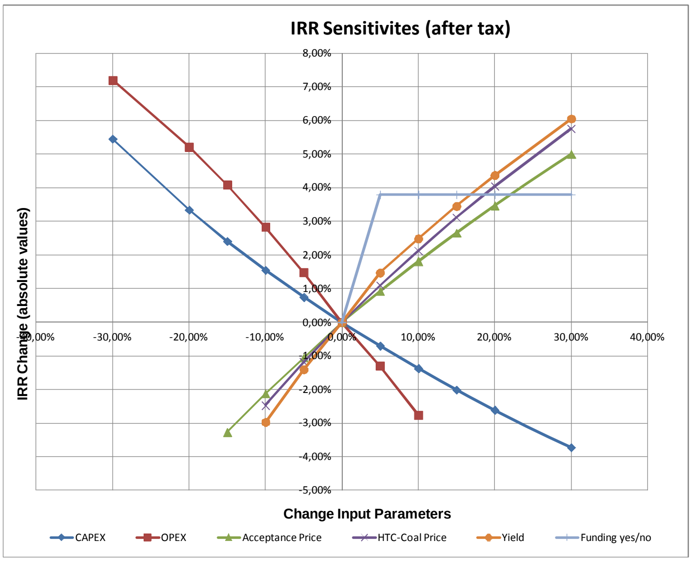
Sensitivities	Input Change	IRR Base Case (after tax)	IRR change (after tax)	rel. Change	IRR Elasticity	NPV Base Case (k€ after tax)	NPV change (k€ after tax)	rel. Change	NPV Elasticity
CAPEX	-10,0%	3,81%	5,36%	40,54%	-4,05	-943,30	-587,8	-37,69%	3,77
	+10,0%		2,44%	-36,01%	-3,60		-1303,4	38,17%	3,82
OPEX	-10,0%		6,65%	74,27%	-7,43		-404,9	-57,08%	5,71
	+10,0%		1,05%	-72,38%	-7,24		-1373,7	45,63%	4,56
Acceptance Price	-10,0%		1,70%	-55,48%	5,55		-1298,1	37,62%	-3,76
	+10,0%		5,62%	47,42%	4,74		-604,3	-35,94%	-3,59
HTC-Coal Price	-10,0%		1,34%	-64,80%	6,48		-1350,4	43,16%	-4,32
	+10,0%		5,94%	55,75%	5,57		-542,9	-42,45%	-4,25
HTC-Process Water Price	-10,0%		3,81%	0,00%	0,00		-943,3	0,00%	0,00
Price	+10,0%		3,81%	0,00%	0,00		-943,3	0,00%	0,00
Yield	-10,0%		0,85%	-77,85%	7,78		-1424,6	51,02%	-5,10
	+10,0%		6,30%	65,18%	6,52		-470,5	-50,12%	-5,01
Funding yes/no			7,61%	99,52%	-4,38		-145,1	-84,61%	-3,72

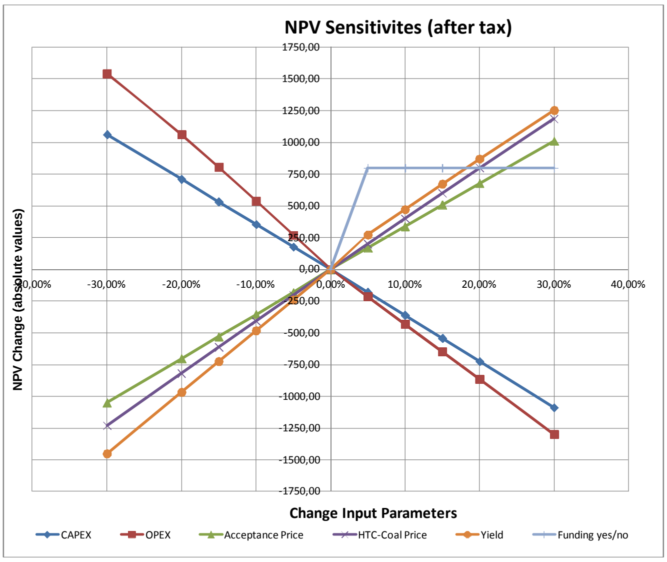












ANNEX 5

Annex 5

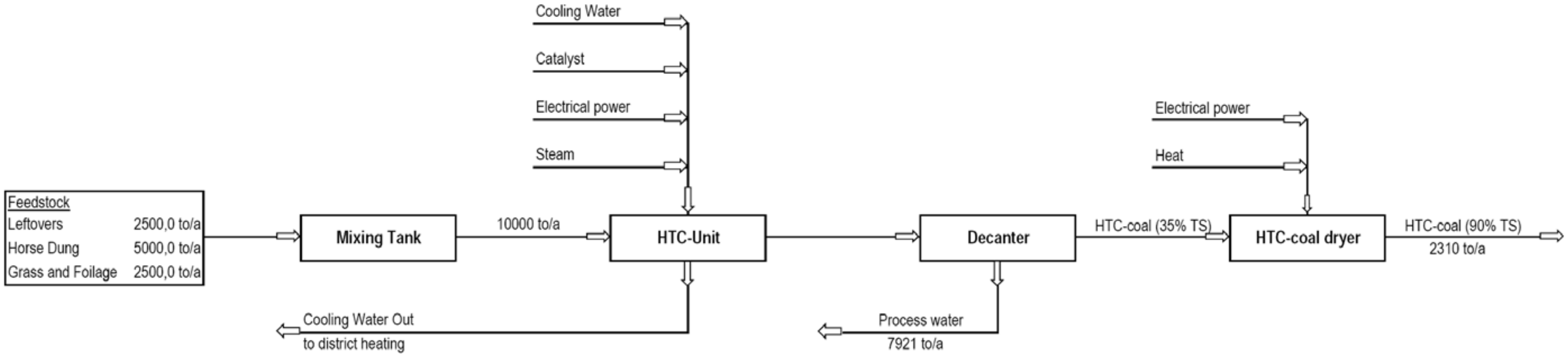


Figure 25. Simplified Flow Diagram of case model.