Journal of Sustainable Development; Vol. 10, No. 6; 2017
ISSN 1913-9063 E-ISSN 1913-9071
Published by Canadian Center of Science and Education

Economic Evaluation of Bioenergy Production from Bio-based plants in Germany: Implications for the bioeconomy?

Martin Paul Jr. Tabe-Ojong[1] & Naphtal Habiyaremye[1]

[1] Institute for Food and Resource Economics, University of Bonn, 53113, Bonn, Germany

Correspondence: Martin Paul Jr. Tabe-Ojong, Hirschbergerstr. 58-64, 53119 Bonn Germany.

E-mail: tabeojongmartinpaul@gmail.com; habiyaremyen@yahoo.fr

Received: October 9, 2017 Accepted: November 1, 2017 Online Published: November 29, 2017

doi:10.5539/jsd.v10n6p262 URL: https://doi.org/10.5539/jsd.v10n6p262

Abstract

The production of bioenergy from plant sources has been an emerging issue in the global bioeconomy. This is as a result of the depletion of fossil fuel sources and its high adverse effects on the environment as the main source of conventional energy. Bio-based products from fruit trees and crops have been thought and proven to play an important role in supplying future bioenergy and contributing to the achievement of some sustainable development goals. Many studies have focused on this novel technology without focusing on the economic aspect of it. In a bid to build and improve on literature, this study sought to economically evaluate the production of bioenergy from biomass using robust and standard profitability measures like the net present value (NPV), internal rate of return (IRR) and the payback period (PBP). Data was obtained through expert interviews from the Klein-Altendorf project site in Bonn, Germany. A business as usual scenario and a carbon avoidance scenario were investigated to ascertain the economic viability of this sustainable activity. Results in the business as usual scenario showed the process as a non-profitable venture. However, based on the carbon avoidance scenario, we argued that the project is economically viable especially in terms of carbon avoidance which reduces emissions and goes a long way to protect the environment. These social benefits obtained make the investment worthy. The greatest constraint and cost come from establishing such initiatives. The study found initial investment costs to be very high. Moreover, bioenergy produced is valued at the same price like energy produced from fossil fuels despite its numerous benefits to the environment. The results recommend to policy the maintenance of such initiatives as they have a big role to play in the global bioeconomy. In addition, other countries should join Germany in supporting this initiative by subsidising producers of bioenergy. This is justifiable and arguably the reason for Germany's global recognition in bioeconomic issues.

Keywords: Bioenergy, bio-based plants, bioeconomy

1. Introduction

Over the last two decades, the supply and production of energy have been restructured worldwide (Gold & Seuring, 2011). Different countries have been trying to find innovations of new systems and technologies capable of providing fossil fuels substitution. This is due to the scarcity of sources of fossil fuels and high environmental impacts as the main provider of energy (Shafiee & Topal, 2009). There is no doubt that, as the world develops, the sources of conventional energy are quickly reducing due to high demand for energy, hence the fear to meet future energy demand which is anticipated to be very high. Bio-based products from fruit trees, crops, and wood are needed as substitutes for fossil-fuel (Chum & Overend, 2001; Maack et al., 2017).

Various authors argue that lignocellulose biomass will play an important role of supplying future bioenergy, and subsequently contributing to sustainable development goals (El-Chichakli, 2016; Maack et al., 2017). Fussrthermore, Chum and Overend (2001) posit that, biological resources can considerably contribute a greater share of the needed renewable energy. To meet the future's demand of energy, biomass needs to be utilized since it is the most available and affordable source of renewable energy (Romański et al., 2014). For instance, the IPCC report of 2011 shows that renewable energy sources occupied 12.9% of all primary energy supplied in 2008, of which 10.2% was from biomass (IPCC, 2011, p. 6). Romański et al. (2014) established that fruit trees such as apples, pears, cherry, walnut, and plum together with *Miscanthus* are the main sources of renewable energy in many countries across Europe. Such findings support the opinion of Smith et al.(2000) who suggest that infrastructure for bioenergy production should be enhanced for its full exploitation. This will reduce the use of fossil fuels and increase the use of environmental friendly energy.

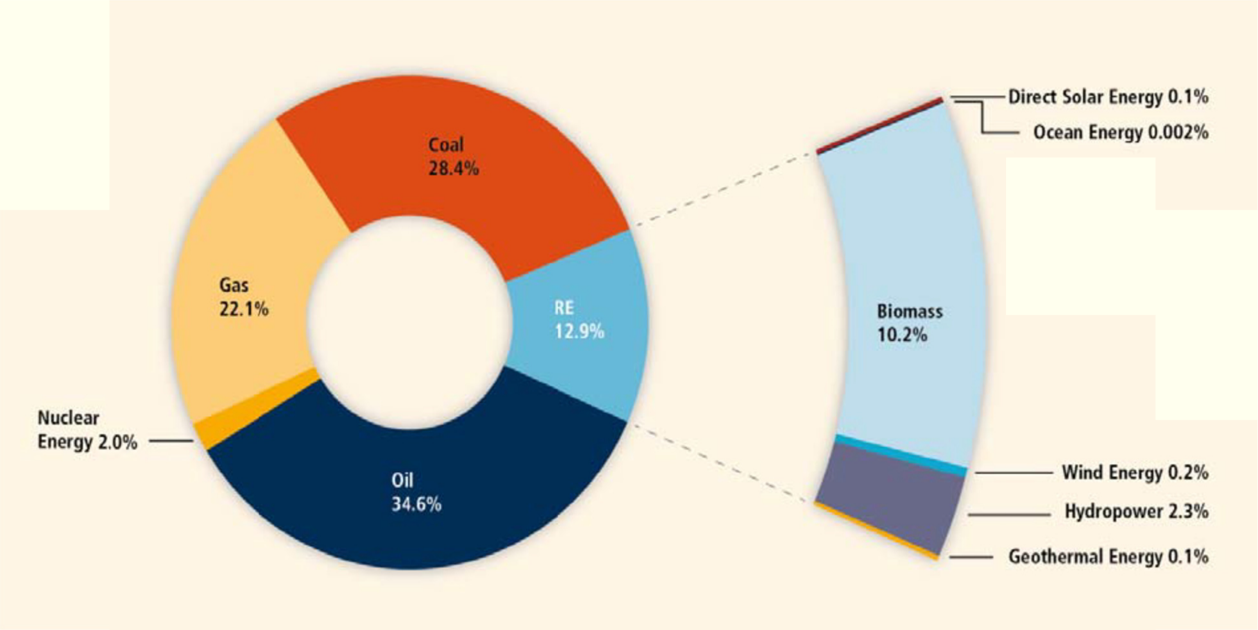

Figure 1. Shares of energy sources in total global primary energy supply in 2008 (IPCC, 2011, p. 6)

Bioenergy sources have several advantages compared to fossil fuels. For example, when biomass is burnt, the carbon released in the atmosphere is equivalent to CO_2 absorbed by the same biomass during its photosynthetic growth (Abbasi & Abbasi, 2010). During this process, it is assumed that there is no additional CO_2 released making the process 'carbon-neutral'. In contrary, fossil fuels burnt generate a lot of additional CO_2 in the atmosphere due to the fact that they are derived from animals and plants that lived so many years ago and sequestrated so much carbon (Abbasi & Abbasi, 2010; York, 2012). This has made biomass to be seen as 'carbon neutral' in comparison to fossil fuels which are 'carbon positive' (Abbasi & Abbasi, 2010; IPCC, 2011).

As the world embarks on substituting fossil fuels, technologies of biomass production are improving as well (IPCC, 2011; Thornley & Cooper, 2008) . Sustainable biomass can play an important role in helping to address concerns about climate change, while contributing to economic growth and generating employment opportunities, particularly in rural areas (EU, 2014).

The suitability of biomass for electricity generation, fuels, cooling and heating, makes it unique compared to other renewable sources (Brenner, 2012; Thornley & Cooper, 2008). This has led to the development of several policies to enhance the sector across the world. For instance, the European Union (EU) policy on bioenergy which aims to reduce greenhouse gas emissions and the dependence on imported fossil fuels, and to diversify its sources of energy supply (Kraemer & Schlegel, 2007). This policy aims that 20% of all EU energy consumption should come from renewable sources by the year 2020.

The German government since then set targets higher than EU and introduced various policies such as subsidies, feed-in tariffs to regulate energy market (Brenner, 2012, p. 13). These policies target a 30% electricity share from renewable energy, a 7% reduction of greenhouse gas, a 14% heat generated from renewable energy by 2020. The policies furthermore target to use biofuels in order to reduce greenhouse gas emissions from transport (BMU, 2009). In addition, the policies intend to achieve an 80% reduction in CO_2 emission by 2050 (Bickel et al., 2005). As a result, the National Biomass Action Plan shows that 12.3% of Germany's total energy consumption in 2013 was from renewable sources while 62% of this was credited to bioenergy (Lupp et al., 2014). Based on the above, Germany received worldwide recognition for being a key player in promoting the use of renewable energy sources.

However, the great achievement of the German government is arguably associated with high investment in technologies for biomass production. Figure 2 illustrates the country's investment in renewable energy sources between the periods of 2000 to 2015. Such achievement is credited to both technological and financial investments. For example, biomass installations receive financial support from renewable tariffs paid by consumers. In 2015, the German Association of Energy and Water Industries (BDEW) estimated the amount of 6.2 billion euros paid to bioenergy producers as payments for electricity under the Renewable Energy Act (CLEW, 2016).

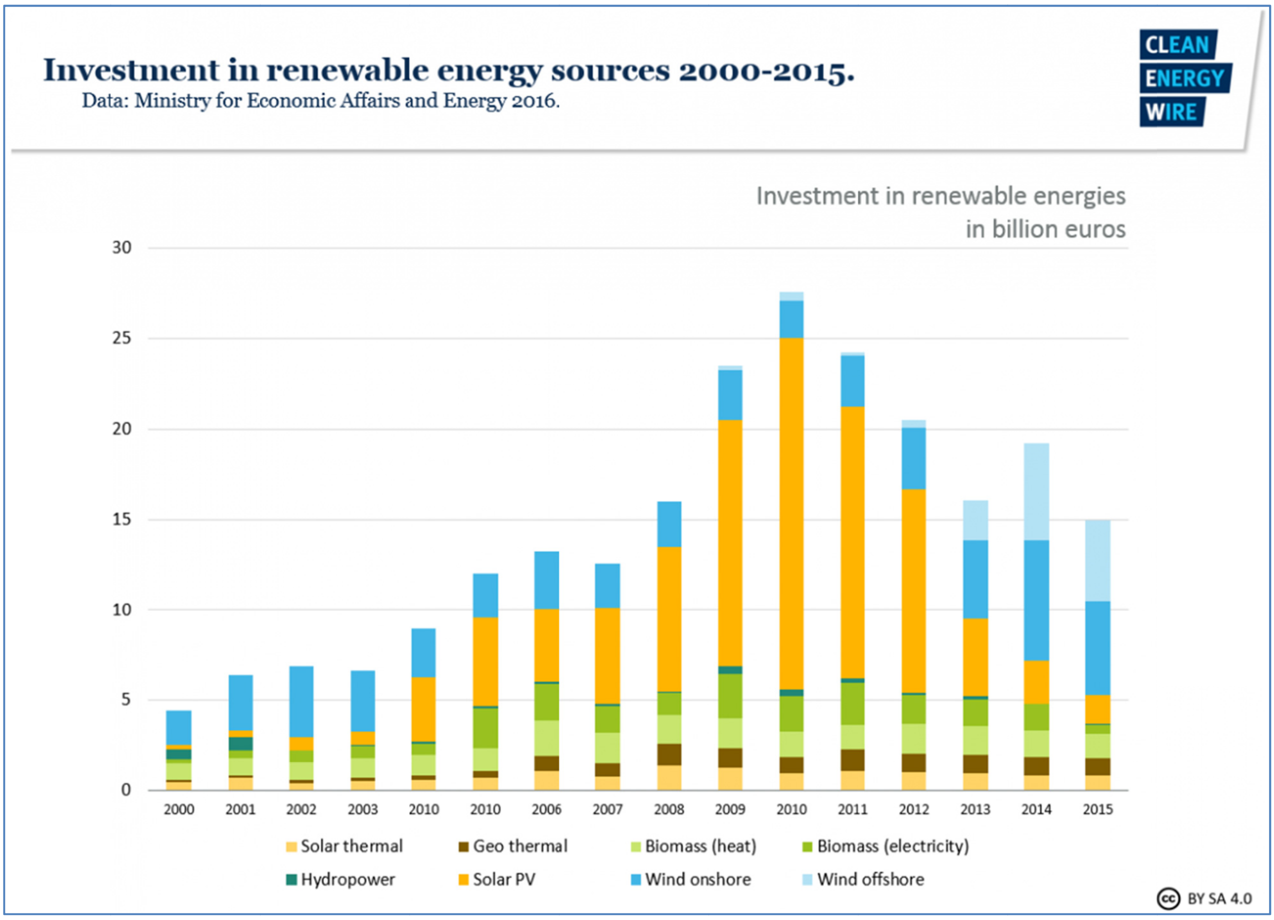

Figure 2. German investment in renewable energy sources 2000-2015 (CLEW, 2016)

The above investments made by the German government brought numerous profits. For instance, in 2015, greenhouse gas emissions reduced by 61.3 million tonnes of CO_2 due to renewable energy use. This made Germany to prevent CO_2 emissions equivalents of 156.1 million tonnes in total (CLEW, 2016). The avoided greenhouse gas emissions in the three main energy demand sectors can be seen in the graph (Fig.3) below. The graph also displays the share of each of the renewable energy avoided by specific energy sectors in 2015. From the graph, biomass has contributed a lot in avoiding greenhouse gas emissions. It took the highest share in heating sector by avoiding 30 million tonnes of CO_2 equivalent emissions, and it is second in electricity sector with an avoidance of 25 million tonnes. Excitingly, it was the only renewable energy source that reduced greenhouse gas emissions in transport sector in 2015

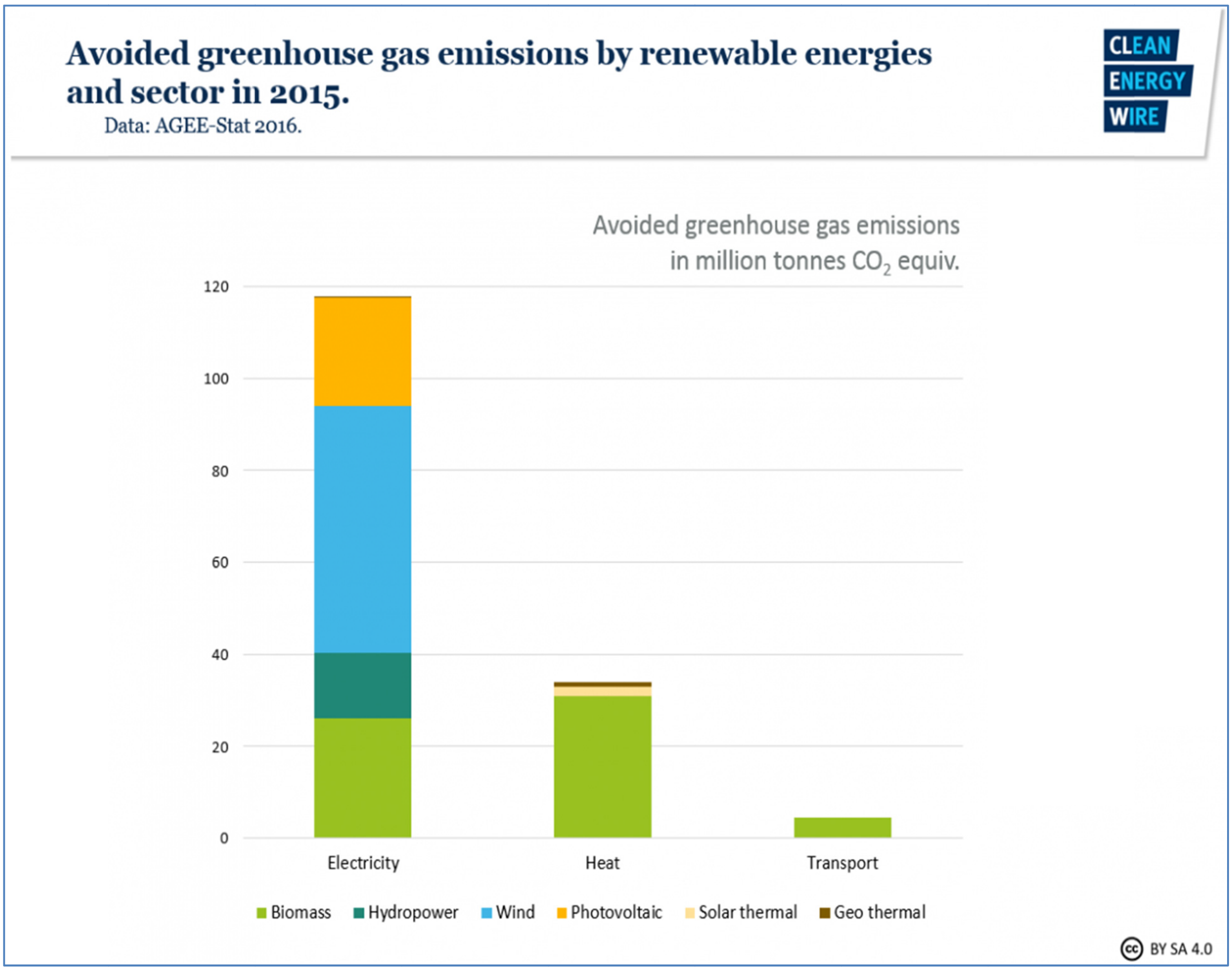

Figure 3. Avoided greenhouse gas emissions by renewable energies and sector in 2015 (CLEW, 2016)

Despite the above substantiation, the pressing concern remain to empirically establish the feasibility of such initiative and to determine at what extent such investment are economically viable. Very few studies have so far been carried out to generate such knowledge. This drove our scientific curiosity towards the economic feasibility of such initiatives.

Taking into account the above gap, the objective of this study was to undertake a cost benefit analysis of heat energy production from biomass. Our study considers the case study of the University of Bonn’s Klein-Altendorf Campus heat energy production system. Specifically, the paper seeks to analyse the costs incurred during the production of heat using apple trees and *Miscanthus* and compare with the benefits derived it.

The remaining part of this paper is structured as follows. Section 2 is the project description and section 3 describes the data and methodology used. Section 4 discusses the results obtained and their interpretation while section 5 provides critical discussion of the results. Finally, the conclusion of the paper will be reached on in section 6.

2. Theoretical Background

Unless otherwise stated, all the information in this paper is based on this site visit conducted by the researchers to the Klein-Altendorf project site. The campus Klein-Altendorf is the experimental farm or better still the field laboratory for the Agricultural Faculty of the University of Bonn. The farm is more or less very sustainable with a lot of projects that underpin the role of the sustainable production of resources. One of such projects is the use of Biomass for heating the facility’s green housing equipment. The project is known as ‘AGROHORT: ENERGY’ and it started in 2010. The main source of biomass here are fruit trees such as apples, cherries and pears as well as *Miscanthus*. Cherries and pears are only used to supplement the apples and *Miscanthus* which are constantly used.

Apples and *Miscanthus* are cultivated to a scale of 30 and 8 hectares farm sizes respectively. The productivity of apple trees reduces after 15 to 20 years of growth and are usually cleared to give way for new trees. These cleared trees are generally dried and burnt by Campus Klein-Altendorf for heat production. For *Miscanthus*, it is grown every year without the need for replanting. The project follows a sequence of activities which are clearing, Shredding, Drying, Boiling/Burning, Buffer tank heating and finally greenhouse heating as described below:

Clearing is done using an excavator which removes the plants wholly from the earth along with its roots. The roots are usually estimated to account for a third of the biomass; reason the project factored in the root biomass potential during implementation. A total of 2500 apple trees are grown per hectare. The campus follows an internal policy of clearing 5% of the total number of hectares committed to growing apples every year. This is equivalent to 1.5 hectares of apple trees. These trees have an estimated quantity of 15 tonnes per hectare of biomass. For *Miscanthus*, all the 8 hectares grown are harvested using a combined harvester, similar to those used for maize. *Miscanthus* is always harvested dry from the field and generally produces 20 tonnes per hectare due to its high yielding capacity.

After the biomass has been cleared, shredding is done to effectively reduce the size of the trees wholly. Size reduction (grinding) is one of the major pre-processing operations in using biomass as a source of energy (Naimi et al.,2006). By shredding, trees are reduced to a size that is suitable for the boiler. This is carried out with the aid of a biomass shredder.

The shredded biomass is dried using a solar dryer. Klein-Altendorf uses a new but very expensive system for drying its biomass. The system is more efficient and effective than the contemporary dryers which take a longer time to dry biomass. Drying is usually done to reduce the moisture content in the biomass to about 20%. Apple trees are dried for 12 to 14 weeks to reach this 20% moisture content. Drying is usually performed in summer time for better performance of the solar dryers. As a result, trees are usually cleared from December to January. Since m*iscanthus* is generally dry at harvest period, it does not require any drying process.

Dried biomass is usually boiled/burnt in a biomass Boiler. This is a box-shaped equipment that burns the biomass.

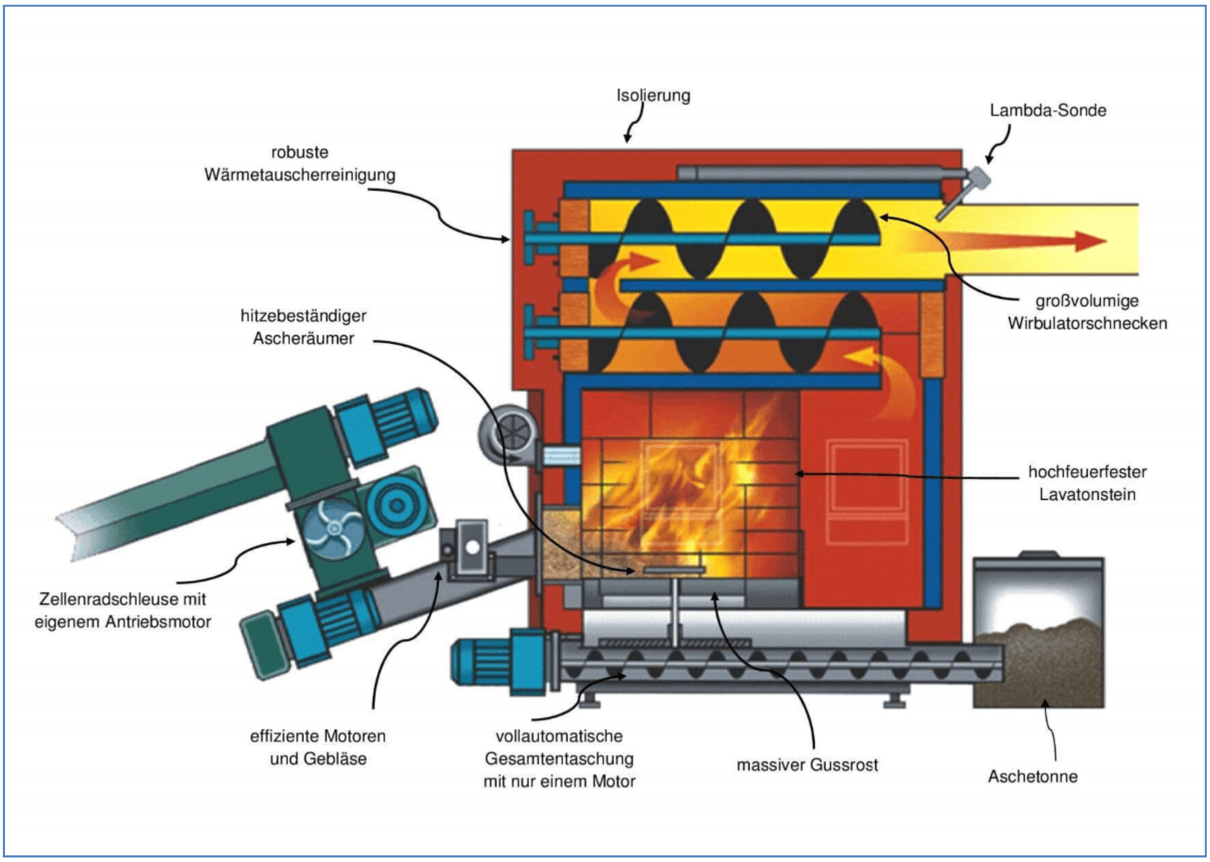

Figure 4. Burning Process

http://www.doepik.com/wp-content/uploads/schnittzeichnung-hsk-ra-bis-200-kw.png

The boiler has a lot of accessories and involves several steps. Firstly, the dried biomass is led into the boiler using well-constructed boiler compartments. These compartments function better with *miscanthus* than with the trees since the latter are heterogeneously shredded.

Boiling is ignited from an electrical energy source which leads to the burning of all the biomass. The boiler has a power rating of 450kW/h and an economic life of 15 years. It operates at an efficiency rate of 85% and has a 4 to 11% resistant rate for ash. The ash is usually collected at the bottom of the boiler. Annually about 2000 to 2500m^3 of biomass is boiled. Heat energy is basically produced in an oxidative process called Combustion. *Miscanthus* has a lower density than apple trees and usually produces more heat and ash. Apple biomass is estimated to produce about 18 MJ/Kg of energy while *miscanthus* produces about 19 MJ/Kg of heat energy. The heat generated by the boiling is led to the buffer tanks through well-constructed and insulated pipes. There are two buffer tanks, each having a volume of 45,000 litres. These tanks are also well insulated and can store hot water for 2weeks. This is a great advantage as boiling can be carried out just in a two week interval. The buffer tanks are connected by pipes to the heating system of the green houses while the heated water is converted in the heating system to provide heating for the green house facility.

The last stage of the processing sequence is heating the greenhouses. The generated heat is used to provide heating for the green houses. Every year, about 5000m^2 of greenhouses comprising of six facilities are heated with a total of 3,961,000 MJ of energy equivalent to the heat energy demand of 10 to 12 houses, assuming that each household uses about 50kW of energy.

3. Materials and Methods

3.1 Data

This study relied primarily on data collected from the project site in Klein-Altendorf. We employed the expert interview approach for data collection. We interviewed the project coordinator on vital questions ranging from heat processes to the monetary values attached to these processes. Investment costs such as the cost of the biomass based boiler, the solar dryer and the boiler accessories like the buffer tanks and pipes and the daily operational cost which included the excavator services are captured in our Cost Benefit Analysis (CBA).

We used the standard cost for wood chipping which is 9.25 EUR/m^3 for the wood chipping and refining cost while the labour cost in the form of salaries was estimated based on the German scale for technicians working in agricultural enterprises on a part time basis. For instance, workers were categorized under E-9 salary scale. This is a salary scale for skilled labourers in Germany.

Transportation cost was estimated using ‘KTBL, Operational planning Agriculture 2016/2017; Data for farm planning in agriculture’ taking into account that the transportation of both *miscanthus* and apples is in the range less than 10 km. No administrative costs such as taxes or license cost was associated with the project since it is a public institution belonging to the University of Bonn.

The cost of growing apples is not factored in our analysis since the main purpose for their cultivation is the production of fruits, and generally, they are cleared and replaced after an estimated 15 year period. Most farmers either burn them after paying for its eventual clearing. Unlike the apple trees, *miscanthus* is grown for its energy purposes. As a result of this, production cost for the cultivation of *miscanthus* is captured in our analysis and adapted from Haverkamp & Mußhoff (2011), since this cost is not estimated in the Klein-Altendorf project.

For the benefits, we evaluated the quantity of heat generated from the estimated yield level of the crops. For apples cultivated on 1.5 hectares, we estimated the yield to the level of 22.5 tonnes per year. The quantity of heat generated from heating apple biomass was estimated to be 18 MJ/kg. Hence the total quantity of heat energy generated from apple biomass was 405,000 MJ. Applying the same reasoning to *miscanthus* cultivated on 8 hectares, with a yield level of about 20 tonnes/hectare and 19 MJ/kg of heat energy, the total energy obtained was 3,040,000 MJ. After factoring in our analysis the biomass based boiler 85% energy efficiency level, the total energy for *miscanthus* and apple trees were estimated to be 2,584,000 MJ and 344,250 MJ respectively

The price of heat energy per KWh from oil and gas was obtained from the Stadtwerk, Bonn, and estimated at 70ct/KWh. Based on the argument of Hoffman and Weih (2005) that prices for biomass heating compete with prices for oil and gas heating, we made the assumption that the price for heat energy from biomass is also equal to 70ct/KWh. We considered the economic lifespan of the machines to be 15years as per the operational manuals. We assumed a 10% residual value for the machines, which represents the selling price of the machines at the end of the lifespan of the machines.

Furthermore, we used the already calculated figures from Innovation Park at Klein altendorf to estimate the amount of CO_2 avoided. The price of CO_2 avoided in Germany was estimated to be 194.80EUR/tonne based on

Bickel et al. (2005). This value is pretty high as compared to other EU countries. The high value is based on an 80% reduction in CO_2 emission by 2050 compared to 1987 (Bickel et al., 2005).

3.2 Estimation Method

We used the Cost benefit analysis (CBA) to estimate the production of energy from biomass. CBA is a major business analytical and appraisal tool that has two main purposes: (1) Determine if an investment is feasible and (2) serve as a basis for comparing projects based on the allocation of resources (Pearce et al., 2006). The CBA has enjoyed fluctuating fortunes, but is still recognized as the major appraisal technique for public investments and public policy (Pearce et al., 2006). For a project or policy to be considered economically worthy, its benefits must exceed its costs. The costs and benefits are usually compared on equal terms; thus, implying the use of the net present value (NPV) as one of the most frequently used measure of profitability. Witzel and Finger (2016) purported that the NPV is one output value of the discounted cash flow method, showing today's value of future payments minus initial costs. The concept of NPV brings to lamp light the notion of discount rate which is usually defined as a pricing mechanism for the time value of money, or simply put, the rate at which future cash-flows are adjusted to present day.

The choice of the discount rate is an important issue as higher values will likely hinder biomass and favour fossil fuels due to higher investment requirements of the former (Kovacevic and Wesseler, 2010). However, setting the discount rate too low also makes the project to suffer from the risk of an economically inefficient investment. Odgaard et al. (2005) purported that discount rates in the EU vary from 3-8%. Likewise, Bickel et al. (2005) and Evans (2006) opined the use of 5% social discount rate. Based on their findings, we used a discount rate of 5% while a 3% discount rate scenario was considered in the sensitivity analysis among many other scenarios. The purpose of sensitivity analysis is to show how large the risks of a project are and in particular to show whether a favourable project becomes unfavourable if some assumptions are changed (Bickel et al., 2005). A social benefit scenario was also considered in this study to assess the sustainability of the project. A time period of 15 years (2012 – 2027) was chosen since most of the fixed cost equipment have an economic life of 15 years.

4. Results and Interpretation

Two scenarios were ran for the analyses: one predicting the Standard Cost Benefit Analysis and the second accommodating the Social Benefit of CO_2 emission avoidance.

For the first scenario, the fixed cost amounted to 907,670 € while the operational cost amounted to 41,886 € each year, hence the total cost value of 1,535,960 € for the whole project. The benefits generated for the 15years of the project will be 854,073€ plus the residual value of the machines (90,500 €) giving a total benefit value of 944,570€. The Net Benefits is therefore 591,390 € (944,570 € - 1,535,960 €), implying an economic loss. However, taking to account the discount rate of 5% annually, the NPV of the project will be -707,896€ whereas the yearly PV of net benefits of the project is shown in Figure 5 below.

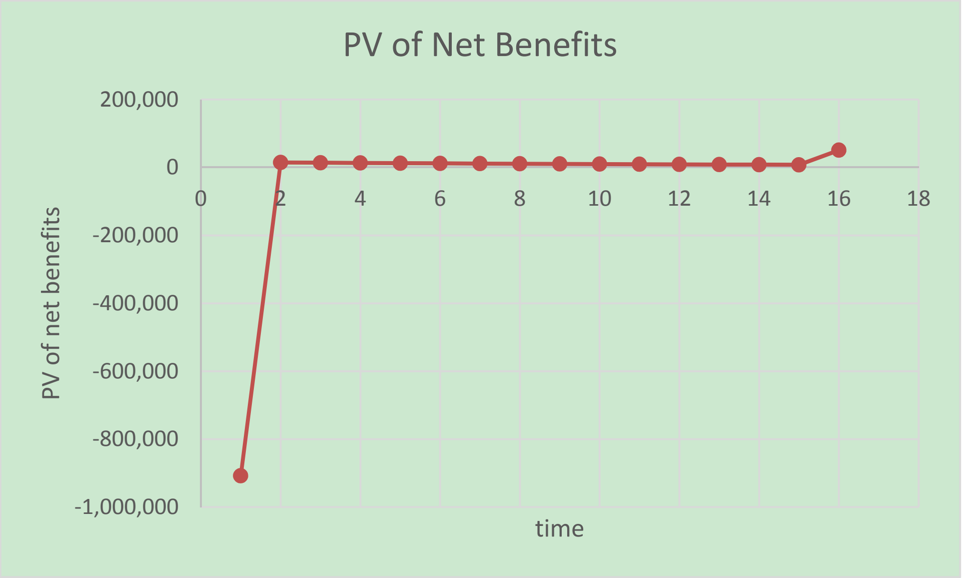

Figure 5. PV of Net Benefits (Source: Authors Computation)

The present value of the yearly benefits start from a very negative value in the year of implementation. This is always the case in the beginning of most projects especially if the cost of purchasing fixed cost items is very high. However, from the first year of implementation, it becomes positive though at a decreasing rate till the 15th year of the project when it increases significantly (See Fig.5). This increase is due to the addition of the residual value of the machines in the last year of the project's life.

The net present value (NPV) negative value for the project (-707,896€) implies that resources are not efficiently allocated, hence we reject the project based on feasibility ground and normal NPV standards and practices.

The internal rate of return (IRR) was also negative with a value of -9%. This is probably due to the initial investment of the project which is higher than the inflows from investments.

The payback period which refers to the time needed to recoup the initial investment of a project or to reach the break-even point does not occur in the assumed project's life time. However, it keeps reducing considerably over the years with no possibility of break-even over the project lifespan.

All the profitability measures (NPV, IRR and Payback Period) are negative and pointing to the rejection direction.

A lot of reasons could explain this behaviour. Firstly, the initial investment costs are very high. These include the costs of purchasing fixed items like the biomass based boiler, the solar drier and the boiler facilities. The campus at Klein-Altendorf makes use of an advanced solar dryer which is rarely used by other institutions or firms engaging in producing similar bioenergy.

Secondly, the equipment are not being utilized to full capacity as the institute is constrained by the yearly tonnage of biomass available. The boiler for instance, has a power rating of 450KWh but it is not used regularly since it can generate heat energy that is stored in the well-insulated buffer tanks for two weeks.

Thirdly, the Klein-Altendorf campus is oriented into research. Profit making is not their primary goal, instead an added value.

For the second scenario, which entails the social benefit of using biomass for heat energy, we estimated the amount of CO_2 emission being avoided. The total amount of CO_2 avoided by using heat energy from biomass other than from fossil fuels is 204,428.57Kg. A price of 0.1948 €/Kg of CO_2 was adapted from Bickel et al. (2005). This gives a total amount of 39,823€. However this is a monetary benefit which is not being paid to the Klein-Altendorf but it benefits the global environment.

This additional social benefit in the second scenario changes all the profitability measures considerably in the first scenario (NPV, IRR and Payback Period). For that reason, the NPV has a value of -294, 551€ which renders the project still not profitable. The IRR has also reduced to zero. This still indicates the non-profitability of the project since the IRR is less than the Discount rate of 5%. The project is approaching its payback period since the NPV has considerably increased, nevertheless, the payback period is not met in the assumed project's lifespan as per our computation.

4.1 Sensitivity Analysis

All the various profitable measures used in the CBA are negative even after the inclusion of the social benefit of CO_2 avoidance. It becomes important to analyse and establish possibilities of turning this unfavourable outcome into favourable. As a result, sensitivity analysis was performed so establish the effects of changing some major assumptions on the NPV, IRR and the payback period measures.

For example, adjusting the discount rate to 3% leaves the NPV still at a negative value though much higher than the first scenario (CBA) while the IRR stays the same at -9%. This clearly shows that the discount rate has very little impacts on this unfavourable outcome. This is also the case with the inclusion of social benefits (second scenario), wherein the NPV greatly increases though maintaining its negative value while the IRR stays at 0%.

Another example of our sensitivity analysis considered varying the price of heat energy which led to large changes in all parameters. This explains that price is a very sensitive instrument in the production of bioenergy. For instance, any price above 15.4cents leads to a positive NPV and IRR as well as adequate payback of the investment before the project ends. This is even far lesser with the inclusion of the societal benefits in the second scenario.

Increasing the amount of heat energy, *ceteris paribus*, affects the profitability measures significantly. For instance, increasing the amount of heat energy by a scale multiplier of 2.24 results to a positive NPV and IRR which is greater or equal to the discount rate. This holds even better at a lower scale multiplier with the inclusion of societal benefits in our second scenario.

Lastly, in a bid to recheck and economize cost, it was important to establish if a reduction of the fixed cost will greatly increase the profitability measures and subsequently turn the unfavourable outcome of the CBA into favourable. From our computation, reducing the fixed cost to about half of its original value led to a positive NPV and a favourable outcome in the both scenarios. Based on the above four sensitivity analysis cases, we can conclude that the optimization of the above parameters result into positive and a favourable outcome, arguably due to the fact that they are critical factors in the production of bioenergy from bio-based plants.

5. Discussion

From the Cost Benefit Analysis we rejected the project at Klein-Altendorf as not being economically efficient. We found that the project incurred very high investment costs at its inception, through the purchase of equipments like Solar dryer and the biomass based boiler. The NPV for the project was negative. This implied the non-profitability of the project. We argue that this negative value is linked to the high investment cost and price of heat energy. Generally, the investment costs for installing a bioenergy facility is very high as compared to fossil energy plants, since bioenergy requires a bigger fuel storage (wood chips and pellets need more space and a more expensive technique to transport the biomass into the combustion chamber), and filters in order to ensure the emission limits (Bloche-Daub and Schmidt-Baum, 2015). As a result of these high costs, the payback period for bioenergy plants is significantly higher compared to fossil fuel plants (Bloche-Daub and Schmidt-Baum, 2015).

The other reason for non-profitability of the project is the use of expensive and sophisticated machines for bioenergy generation. Most commercial oriented bioenergy producers will not venture into such expensive equipment, instead, they would prefer cheaper but efficient options. More so, the biomass based boiler is not used to full capacity. Brenner (2012) opined that biomass heaters generally achieve higher efficiency if they run at almost full capacity which is not the case in this project.

The price for heat energy from biomass in Germany is very low as compared to other countries in the EU. For instance, in a study conducted in Poland (Kovacevic and Wesseler, 2010), established that the price of heat energy generation from willow biomass was 0.1322€/KWh compared to 0.07€/KWh in Germany. Hence the operation of a big and an expensive bioenergy plant is undesirable in scenarios where the price of heat energy is low like in our Klein-Altendorf case. Also, investing in an expensive bioenergy plant is not profitable when the energy price are too low (Bloche-Daub and Schmidt-Baum, 2015).

We established that the implementation of the social benefit scenario greatly increased all the profitability measures. The profit could be even more if the biomass based boiler operated at its full capacity of 450KWh. Furthermore, the use of bioenergy plants for generating heat energy is a positive step towards achieving Germany's CO_2 reduction emission targets by 2050. The environment will benefit more and the process will become profitable too. Burning solid biomass (the most common biomass conversion route) emits more CO_2 per unit of energy generated than fossil fuels (Bourguignon, 2015). Hence it is worthwhile investing in bioenergy. As a result of the numerous importance of bioenergy for environmental conservation and sustainability, the government is supporting producers of such technologies by enacting various policies such as The Renewable Energy Heat Act, Gas Grid Access Ordinance, Renewable Energy Sources Act and Combined Heat and Power Act, which advocate for the use of renewable-generated heat in new buildings and solid biomass at 50% minimum share (BMU, 2009; Matthias Edel et al., 2016). Likewise, the German Renewable Energy Heat Act (Erneuerbare-Energien-Wärmegesetz, or EEWärmeG) came into effect on 1 January 2009 that require owners of newly constructed houses to meet their heating requirements by using renewable energy.

Despite the increasing support by the German government to up mend the use of bioenergy, it is important to mention some of the potential threats to the society. Some of these threats are unsustainable feedstock production; emissions from land use, land use change and forestry (LULUCF); lifecycle GHG emission performance; indirect impacts; inefficient bioenergy generation; and air emissions, among others.

6. Conclusion

The cost benefit analysis of producing heat energy from biomass at Klein-Altendorf was carried out to determine the profitability and viability of this sustainable practice. The results established that the project is not profitable because it is associated with very high costs of implementation compared to its monetary benefits. These high costs made the NPV of the project negative. Other profitability measures investigated were the internal rate of return and the payback period.

Factors leading to high costs of the projects were identified, among them, the use of expensive facility and the inability to operate the heat energy production unit to full capacity.

However we argue that the project should not be abandoned because of its social benefits of reduced emissions as demonstrated in the second scenario. These social benefits make the investment worthy with positive implications for the global bioeconomy. Compared to apple trees, *Miscanthus* was found to have high yielding capacity hence the need to improve its production for generating heat. The German government's huge supports to producers of bioenergy is therefore justifiable and arguably the reason for its global recognition.

Acknowledgement

The authors are grateful to Felix Winzer for his useful inputs on various aspects of Miscanthus cultivation and the biomass project at Klein-Altendorf. Special thanks to Mashauri Muliro and Christoph Paymeyer for their helpful comments and insights on the CBA.

References

Abbasi, T., & Abbasi, S. (2010). Biomass energy and the environmental impacts associated with its production and utilization. *Renewable and Sustainable Energy Reviews, 14*(3), 919-937. https://doi.org/10.1016/j.rser.2009.11.006

Bickel, P., Burgess, A., Hunt, A., Laird, J., Lieb, C., Lindberg, G., & Odgaard, T. (2005). Developing Harmonised European Approaches for Transport Costing and Project Assessment: State of the art in project assessment.

Bloche-Daub, K., & Schmidt-Baum, T. (2015). Germany's promising market segments for heating with solid biomass: Horizon 2020 Coordination and Support Action number 646495: Bioenergy for business "Uptake of solid Bioenergy in European Commercial Sectors.

BMU, B. (2009). National biomass action plan for Germany. Biomass and sustainable energy supply. Federal Ministry for the Environment. Nature Conservation and Nuclear Safety (BMU), Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), Berlin.

Bourguignon, D. (2015). Biomass for electricity and heating: opportunities and challenges.

Brenner, C. (2012). Economics of solid biomass heating in Germany, MSc, Norway, Norwegian school of Economics.

Chum, H. L., & Overend, R. P. (2001). Biomass and renewable fuels. *Fuel processing technology, 71*(1), 187-195. https://doi.org/10.1016/S0378-3820(01)00146-1

CLEW. (2016). Bioenergy in Germany – facts and figures on development, support and investment. Retrieved from https://www.cleanenergywire.org/factsheets/bioenergy-germany-facts-and-figures-development-support-and-investment

El-Chichakli, B. (2016). Five cornerstones of a global bioeconomy.

EU. (2014). Commission Staff Working Document: State of paly on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU.

Gold, S., & Seuring, S. (2011). Supply chain and logistics issues of bio-energy production. *Journal of Cleaner Production, 19*(1), 32-42. https://doi.org/10.1016/j.jclepro.2010.08.009

Hoffmann, D., & Weih, M. (2005). Limitations and improvement of the potential utilisation of woody biomass for energy derived from short rotation woody crops in Sweden and Germany. *Biomass and Bioenergy, 28*(3), 267–279. https://doi.org/10.1016/j.biombioe.2004.08.018

IPCC. (2011). Summary for Policymakers. In: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation.

Kovacevic, V., & Wesseler, J. (2010). Cost-effectiveness analysis of algae energy production in the EU. *Energy Policy, 38*(10), 5749–5757. https://doi.org/10.1016/j.enpol.2010.05.025

Kraemer, R., & Schlegel, S. (2007). *European Union policy on bioenergy.* Washington, DC, USA: German Marshall Fund.

Lupp, G., Steinhäußer, R., Starick, A., Gies, M., Bastian, O., & Albrecht, J. (2014). Forcing Germany's renewable energy targets by increased energy crop production: A challenge for regulation to secure sustainable land use practices. *Land Use Policy, 36*, 296-306. https://doi.org/10.1016/j.landusepol.2013.08.012

Maack, J., Lingenfelder, M., Eilers, C., Smaltschinski, T., Weinacker, H., Jaeger, D., & Koch, B. (2017). Estimating the spatial distribution, extent and potential lignocellulosic biomass supply of Trees Outside

Forests in Baden-Wuerttemberg using airborne LiDAR and Open StreetMap data. *International Journal of Applied Earth Observation and Geoinformation, 58*, 118-125. https://doi.org/10.1016/j.jag.2017.02.002

Matthias Edel, Klaus Völler, Toni Reinholz, Senta Schmatzberger, Matthias Mossbauer, Asha Singh, & Panoutsou, C. (March, 2016). Integrated biomass policy frameworks GERMANY. Retrieved from https://www.dena.de/fileadmin/dena/Dokumente/Themen_und_Projekte/Erneuerbare_Energien/Biomass_Policies/Integrated_biomass_policy_frameworks_-_Germany-1.pdf

Naimi, L. J., Sokhansanj, S., Mani, S., Hoque, M., Bi, T., Womac.F, A., & Narayan, S. (2006). Cost and Performance of Woody Biomass Size Reduction for Energy Production. 2006 CSBE/SCGAB, Edmonton, AB Canada, July 16-19, 2006. https://doi.org/10.13031/2013.22065

Pearce, D. W., Atkinson, G., & Mourato, S. (2006). Cost-benefit analysis and the environment: Recent developments, Organisation for Economic Co-operation and Development Paris.

Romański, L., Dyjakon, A., Adamczyk, F., & Frąckowiak, P. (2014). Problems with deriving the fruit tree pruned biomass for energy use. *Agricultural Engineering, 18.*

Shafiee, S., & Topal, E. (2009). When will fossil fuel reserves be diminished? *Energy policy, 37*(1), 181-189. https://doi.org/10.1016/j.enpol.2008.08.016

Smith, P., Powlson, D. S., Smith, J. U., Falloon, P., & Coleman, K. (2000). Meeting Europe's climate change commitments: quantitative estimates of the potential for carbon mitigation by agriculture. *Global Change Biology, 6*(5), 525-539. https://doi.org/10.1046/j.1365-2486.2000.00331.x

Thornley, P., & Cooper, D. (2008). The effectiveness of policy instruments in promoting bioenergy. *Biomass and Bioenergy, 32*(10), 903-913. https://doi.org/10.1016/j.biombioe.2008.01.011

York, R. (2012). Do alternative energy sources displace fossil fuels? *Nature Climate Change, 2*(6), 441-443. https://doi.org/10.1038/nclimate1451

Witzel, C.-P., & Finger, R. (2016). Economic evaluation of Miscanthus production – A review. *Renewable and Sustainable Energy Reviews, 53*, 681–696. Retrieved from www.cia.gov/library/publications/the-world-factbook/fields/2207.html

Copyrights