ABSTRACT: Two basically different concepts for biomass conversion are compared in this study. As representative for a thermochemical process, the supercritical water gasification (SCWG) has been chosen. This concept has been implemented at the Karlsruhe Research Center in a pilot plant. Anaerobic fermentation stands for the biological approach. Both processes use a mix of corn silage and cattle manure as feedstock. The SCWG produces a gas stream which is rich in hydrogen and methane as opposed to anaerobic fermentation where methane is the major compound. Therefore the processes have different use functions. In order to compare the processes, the use functions are matched. The technology assessment is oriented at life cycle assessment according to the ISO standard 14040. The life cycle impact assessment is carried out using the Eco Indicator 99 which aggregates the environmental impacts and calculates a single score indicator. The results show that SCWG has lower potential environmental impacts.

Keywords: life cycle assessment (LCA), environmental aspects biomass conversion, hydrogen

1 INTRODUCTION

The most prominent purpose of biomass conversion is to mitigate the environmental load of energy production. For this reason, processes with the lowest impact on the environment have to be identified. This study compares two basically different approaches of biomass conversion. Supercritical water gasification (SCWG) has been chosen as a representative of thermochemical processes. The data basis is provided by an earlier publication from one of the authors about the pilot plant VERENA which is operated at the Karlsruhe Research Center [1]. Anaerobic fermentation stands for the biological approach and is a commonly applied process. The ecological evaluation goes beyond the process itself and includes all supply and disposal processes of the life cycle starting from the extraction of raw materials. The examination ends where the product is ready to use. The use and disposal of the products is disregarded.

2 TECHNOLOGY ASSESSMENT

The technology assessment is oriented at life cycle assessment (LCA) according to the ISO standard 14040. At first, a technical model of the process has to be established. This is done in the Life Cycle Inventory. Both processes use a mix of cattle manure and corn silage as feedstock. The product gas derived from SCWG consists mainly of hydrogen, methane and carbon dioxide, whereas the anaerobic fermentation produces mainly methane and carbon dioxide. The output of the SCWG is the basis for the comparison. It is quantified in the functional unit which is 1 TJ hydrogen and 4.91 TJ compressed natural gas (CNG). To attain comparability, the model of the anaerobic fermentation is extended by steam reforming to comply with the functional unit. Process data for anaerobic fermentation is collected from the ProBas-database [2]. As a result, input and output streams of energy and materials are obtained for each process. For these, supply and disposal processes are taken from the Ecoinvent 2000 database [3] and are included in the examination. The resulting input and output streams are subject to ecological evaluation, which is carried out with Eco Indicator 99 [4]. This is a damage oriented assessment method which analyzes land use, depletion of fossil resources and the fate of substances in the environment. Based on that, effects on the future availability of resources, eco toxicity and human health are calculated. Finally, the damage categories are weighted and aggregated to a single score indicator value. This does not reflect concrete effects in the environment but environmental impact potentials.

3 RESULTS

Figure 1: Results of environmental impact assessment

Anaerobic fermentation has a higher environmental impact potential than SCWG in the case of a combined production of hydrogen and methane.
3.1 Scenarios

In order to identify the process steps which dominate the results, a sensitivity analysis is carried out.

**Table 1**: Results of sensitivity analysis, relative change of the results related to the relative change of the respective input

<table>
<thead>
<tr>
<th></th>
<th>Anaerobic Fermentation</th>
<th>Supercritical Water Gasification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn silage production</td>
<td>69.7 %</td>
<td>79.4 %</td>
</tr>
<tr>
<td>Transport</td>
<td>9.1 %</td>
<td>3.9 %</td>
</tr>
<tr>
<td>Heat supply</td>
<td>8.8 %</td>
<td>6.7 %</td>
</tr>
<tr>
<td>Electricity</td>
<td>4.0 %</td>
<td>4.2 %</td>
</tr>
</tbody>
</table>

The production of corn silage has the highest influence on the results. In the technical model, anaerobic fermentation uses a higher quantity of corn silage in the feed to produce a certain quantity of gas. This contributes to the difference in the results. To evaluate the significance, the scenario “feed” is calculated where both processes use equal amounts of corn silage. In the initial comparison additional use functions of the processes are disregarded. The residues of anaerobic fermentation can be used as fertilizer and the SCWG generates usable thermal energy. In the technical model this additional use is regarded as steam.

The additional use functions are reflected in the scenario “additional use”. The by-products of the processes are added to the functional unit which is calculated to 1 TJ hydrogen, 4.91 TJ CNG, 5.45E+06 kg steam and 3.31E+06 kg inorganic fertilizer. In order to achieve comparability, both processes have to be upgraded with the production steps for the respective missing product. Hence, anaerobic fermentation is extended by a steam generation process using fossil fuels. Since the does not generate inorganic fertilizer at the present stage of development, a completely independent primary production process for inorganic fertilizer has been added.

3.2 Results of the scenarios

![Figure 2: Results of the scenarios](https://example.com/figure2.png)

The results of the scenario “feed” confirm the initial comparison though the difference between the scores is decreased. In the scenario “additional use” all additional functional outputs of the SCWG and the anaerobic fermentation are considered which leads to the best results for SCWG.

4 CONCLUSIONS

Under the investigated conditions the SCWG has a lower environmental impact potential than anaerobic fermentation. The production of corn silage has the biggest influence on the results. Therefore, the key advantage of the SCWG leading to a better environmental performance is its higher gasification yield. The best results for the SCWG are achieved when the thermal energy can be used.

5 OUTLOOK

This study concentrates on the ecological aspects of the processes. To provide a comprehensive assessment, economic and social impacts have to be considered as well.

The data for SCWG is based on results of a pilot plant whereas the data basis for anaerobic fermentation is derived from full scale applications. To close this gap, the data basis for the technical model of the SCWG used in this study has to be refined.

6 REFERENCES


[2] Database from German Environmental Protection Agency, Prozessorientierte Basisdaten für Umweltmanagement-Instrumente, 2005
