POTENTIALITIES AND LIMITS OF THE ANAEROBIC DIGESTION OF MUNICIPLE SOLID ORGANIC WASTE IN AN AGRARIAN REGION IN GERMANY

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SUMMARY: To promote the expansion of renewable energies is stated aim of many countries. The interest in bioenergy is also increasing actually forced by the climate protection goals (REN21, 2009). In Germany about 100 million Mg biogenous waste and residues are energetic usable with consideration of ecological requirements and could supply 4 to 5% of the national primary energy consumption (Faulstich and Greiff, 2007). The separarate collected municipal organic waste can used by anaerobic digestion as supplement to compost plants. Currently in Germany increases the energetic utilization of the organic share in the MSW by anaerobic digestion as supplement to mechanical-biological treatment plants (Scholwin and Nelles, 2009). In both concepts the potential pollutant and contaminants content impact the anaerobic digestion negatively. Reliable data of the MSW organic share in agrian regions in Germany as calculation basic for the energetic potential are not available. That's why more exact investigations to the organic share in the MSW were necessary. The aim of this study is to investigate the energetic potential of an agrarian region in Mecklenburg-Western Pomerania, by anaerobic digestion. Five areas with different habitation structure are identived and investigated. Basic for the biogas related investigations are determination of the total amount, sieving and sorting of MSW at different times (spring, summer, autumn). In the foreground of the laboratory analysis stands the biogas and methane yield and the influence of pollutant and contaminants. Compared with other studies (34%, Kern and Raussen, 2009), the identified organic content in MSW is relatively high, even if only the unpacked kitchen and the garden waste considered together. On average, in spring the organic content was 44.6%, sorted by hand (unpacked kitchen waste and garden waste: 37.1%) and 37.3% at the machanically summer sorting, based on fresh mass. A correlation between organic dry substance content and the various territories could not be found in previous studies. The analysis of the biogas yield and bioactivity tests is still pending. The results are presented in the lecture during the Venice2010 conference. The recent studies showed that the organic in MSW and thus the energy potential by anaerobic digestion from rural areas can be underestimated.

1. INTRODUCTION

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To promote the expansion of renewable energies is stated aim of many countries. The interest in bioenergy is also increasing actually forced by the climate protection goals (REN21, 2009). But the energetic utilization of huge unutilized resources, such as bio-waste and biogenous residues can also help to meet the consumption growth. The share of biomass in renewable energies in Germany is at the moment about 70% (BMU, 2009) and the technical potential up to the year 2030 is estimated between 10 to 15% of the primary energy consumption (Nelles et al., 2009). In Germany about 100 million Mg biogenous waste and residues are energetic usable with consideration of ecological requirements and could supply 4 to 5% of the national primary energy consumption (Faulstich and Greiff, 2007). Currently only a part of this waste is used energetic in biomass heating and power plants (waste wood, bulky waste …) and in biogas plants (kitchen scraps, leftovers from canteens, organic waste from food industry …). But biogas plants use rarely separarate collected municipal biowaste. For example in Mecklenburg-Western Pomerania, an agrarian state in Northern Germany, exist 7 biogas plants that used 300,000 Mg (90,000 Mg dry substance) organic waste from industry and gastronomy and not one that use separate collected biowaste from municipals (Ocik et al., 2008).

The separarate collected municipal organic waste can also used by anaerobic digestion as supplement to compost plants. Advantages are the possibility to use the contained energy (and substitution of fossil fuels) and in the end the organic matter as fertilizer in the agriculture or gardening. Disadvantages are the high investment costs and the technical demanding process management caused the inhomogeneous input. Currently in Germany increases the energetic utilization of the organic share in the MSW by anaerobic digestion as supplement to mechanical-biological treatment plants (MBT plants) (Scholwin and Nelles, 2009). The concepts stand in a way in competition for the biogenous share of the MSW. In both concepts the potential pollutant and contaminants content impact the anaerobic digestion negatively. The biogas and methane yield depends from different parameters: organic dry matter, nutrient content and other as well as for waste the presence or absence of contaminants (for the anaerobic digestion process) and impurities. The biogas and methane yield of the input material must be known for the waste-economical planning. The biogas and methane yield is also a basic parameter for the design of biogas plants. In the case of separate collected biowaste or MSW this parameter fraught with uncertainty. These materials are very inhomogeneous, depend from the area and vary with the season.

The aim of this study is to investigate the energetic potential of an agrarian region in Mecklenburg-Western Pomerania, by use of anaerobic digestion. Basic for the biogas related investigations are determination of the total amount, sieving and sorting of MSW at different times (spring, summer, autumn). In the foreground of the laboratory analysis stands the biogas and methane yield and the influence of pollutant and contaminants.

2. MATERIALS AND METHODS

2.1 Investigation area

The investigated area comprises the administrative district “County of Nordwestmecklenburg” (NWM). This county lies in the northwest of the federal state Mecklenburg-West Pomerania. It takes a surface in the size of 2,076 km². The number of the inhabitants amount 118,315 (DZA M-V, 2009). The economy in the administrative district “County of Nordwestmecklenburg” is traditional characterized by tourism, agriculture and food trade. The fertile grounds favour wide agrarian units with top yields for market crops. The tourism economy has dynamically developed and is a stable and dependable column of the economy. A prominent tourist infrastructure, the best water quality and many attractive holiday offers are brand names and magnet for the steadily increasing stream of holidaymakers.

The investigated area is an economically weaker region. Caused by that fact the value added is low. The demographic development is characterized by an aging society with low birth rates and high drift, especially young people.

Goal of the Mecklenburg-Western Pomerania government is the development of the waste management to a material flow, energy and resource management (AWP M-V, 2008). The collection of MSW takes place by a municipal, private or public-private company in order of the public service institution (county or city).

The waste management of the investigated area is characterized by the separate collecting of paper, glass, plastics and residual waste. Municipal biowaste is not separate collected. Only wastes from gardening are collected in bigger units at several times in the year (e.g. Christmas trees) and after sorting used in biomass heating power plants or by composting. In 2008 5,344 Mg bio- and gardening waste are composted in NWM (DZA M-V, 2009). The common method is to treat the biowaste themselves by composting in the own garden (without meat, bones, sausage products and coocked foods). Organic waste from public kitchens, leftovers from canteens and organic waste from food industry are treated in biogas facilities outside the investigated area.

The assumed amount of organic in the residual waste (MSW) in the investigation area is 4,912 Mg per year. Calculation basics are the 14,448 Mg MSW per year that arises in the county (DZA M-V, 2009) and the 34% average organic share of MSW in Germany (Kern and Raussen, 2009).

The theoretic potential of (municipal) biowaste in the investigation area is 3,336 Mg. Calculation basics are the amount of 47 kg biowaste per inhabitant and year, wich is typical for Mecklenburg-West Pomerania (DZA M-V, 2009) and that 60% of the 118,315 inhabitants in the county are affiliated to the biowaste collection system.

Kern and Raussen (2006) assumed energy content of separate collectes biowaste between 2,150 and 2,795 MJ/Mg. Based on this the energetic potential of the producible biogas of the theoretic collectable biowaste in the investigated region amounts 7,173,438 to 9,325,470 MJ per year.

2.2 Field and laboratory studies

2.2.1 Assessment of the organic share of MSW in the investigation area

Reliable data of the MSW organic share in agrian regions in Germany as calculation basic for the energetic potential are not available. That’s why more exact investigations to the organic share in the MSW were necessary. Five areas with different habitation structure are identived and investigated (Table 1). The investigated areas have rural character without densely built-up areas, whereby the site density increases from territory type 1 to 5.

Table 1 - Selected territory types in the investigated region - county NWM, Germany.

<table>
<tr><th>Territory types</th><th>Description</th><th>Inhabitants/km²
built-up area</th><th>Population density**
Inhabitants/km²</th></tr>
<tr><td>1</td><td>small village (80…100 inhibitants)</td><td>< 500</td><td>26…36</td></tr>
<tr><td>2</td><td>Village (150…260 inhibitants)</td><td>500…1,000</td><td>47…51</td></tr>
<tr><td>3</td><td>small town (2,532 …4,378 inhibitants)</td><td>1,000…1,500</td><td>115…139</td></tr>
<tr><td>4</td><td>district town* - periphery</td><td>> 1,500</td><td rowspan="2">207</td></tr>
<tr><td>5</td><td>district town* - city</td><td>> 1,500</td></tr>
</table>

* Inhabitants district town: 10,809 **Land Statistical Office MV, 2009

The conditions and presumably the willingness for composting of the own biowaste in the own garden decreases from territory type 1 to 5 (plot size, proximity of neighbors, demand for compost).

2.2.1 Sorting investigations

To investigate the organic share in the MSW two sorting actions were realised so far, the spring and the summer sorting. A third sorting in autumn is planned.

For the spring sorting the waste of 40 households (from 222 selected households) was filled from garbage bins into bags and delivered to the bioenergy and waste laboratory at the Rostock University where it was sorted according to different criteria. The spring sorting was performed in April 2010 as described below. First, the trash bags were weighed. After that, every trash bag was sieved to three fractions: coarse fraction (>50 mm), medium fraction (50-8 mm) and fine fraction (<8 mm). The coarse fraction of the individual waste bags was put on a sorting table, and sorted to eleven groups by 4 people. The organic matter was additionally sorted to the four subgroups. Furthermore, the timber group was split up into untreated and treated timber (see table 2).

All groups and subgroups were weighed after sorting. Samples were taken from the organic matter for further analyses. Next, the medium fraction was sorted according to the sorting procedure of the coarse fraction. Afterwards, the groups of the medium fraction were weighed as well. Eventually, the fine fraction of each waste bag was weighed and samples were taken for further analyses.

To improve the representativeness, the sample number was increased the summer sorting in June 2010. The waste of the different territory types was filled from the garbage bins into collection vehicles and delivered to the residual waste treatment plant of Ihlenberg AG near Selmsdorf where it was mechanically sorted according to different criteria. The territory groups 1 and 2 were merged for this sorting. First, a grapple filled the waste of one territory type in a tank. Having been shredded into 220 millimeters pieces the waste was transported through the plant on conveyor belts. Plastics were sorted out by nearinfrared seperators. Then the waste was shredded into 50 millimeters pieces. Ferrous and non-ferrous metals were removed by seperators. In the end, there were four groups of waste - ferrous metals, non-ferrous metals, plastics (Refuse-derived fuel) and the remnant waste (containing organic matter amongst others).

Table 2 - Sorting groups and subgroups.

No.	*Sorting Groups / Subgroups*
1	organic matter: unpackaged kitchen waste, packaged kitchen waste, garden waste, other organic substances
2	Timber: treated timber, untreated timber
3	paper and cardboard
4	plastics
5	glasses
6	metals (ferrous and non-ferrous)
7	textiles
8	electronic waste
9	sanitary waste
10	problematic substances
11	minerals

The four groups were weighed and the data for each territory type logged. Furthermore, samples from the remant waste on the conveyor belt before it entered the rest box were taken. Samples were taken every minute from the current.

Twelve samples were taken from each territory group and assembled to three mixed samples. These samples were brought to the bioenergy and waste laboratory at the Rostock University for further sorting and investigations. Next, we weighed and opened the mixed sample bags and built cone forms out of the content of every bag. After that, we split the cones up into four equal parts. One part was selected for further analyses. The three other parts were discarded. Two randomly selected mixed samples of different territory types were analysed for interfering substances in the organic matter. For example: glasses, metals, plastics, minerals, problematic substances and electronic waste. All of the data was logged on prepared protocol papers for each mixed sample bag.

2.2.3 Biogas and methane yield according to directive VDI 4630

The amount of energy that can be recovered by anaerobic digestion is shown referring to the total energy content, expressed by the upper calorific value. In order to estimate the energetically potential of the organic fraction, the following parameters are measured (VDI, 2006, Weiland, 2001):

- water content according to European Standard EN 12880
- ignition loss according to European Standard EN 12879
- biogas and methane yield according to directive VDI 4630

The biogas and methane yield is measured by means of anaerobic digestion batch tests in technical scale fermenters with a volume of 60 l (figure 1). The number of repetitions is n= 6 due to the inhomogeneity of the materials.

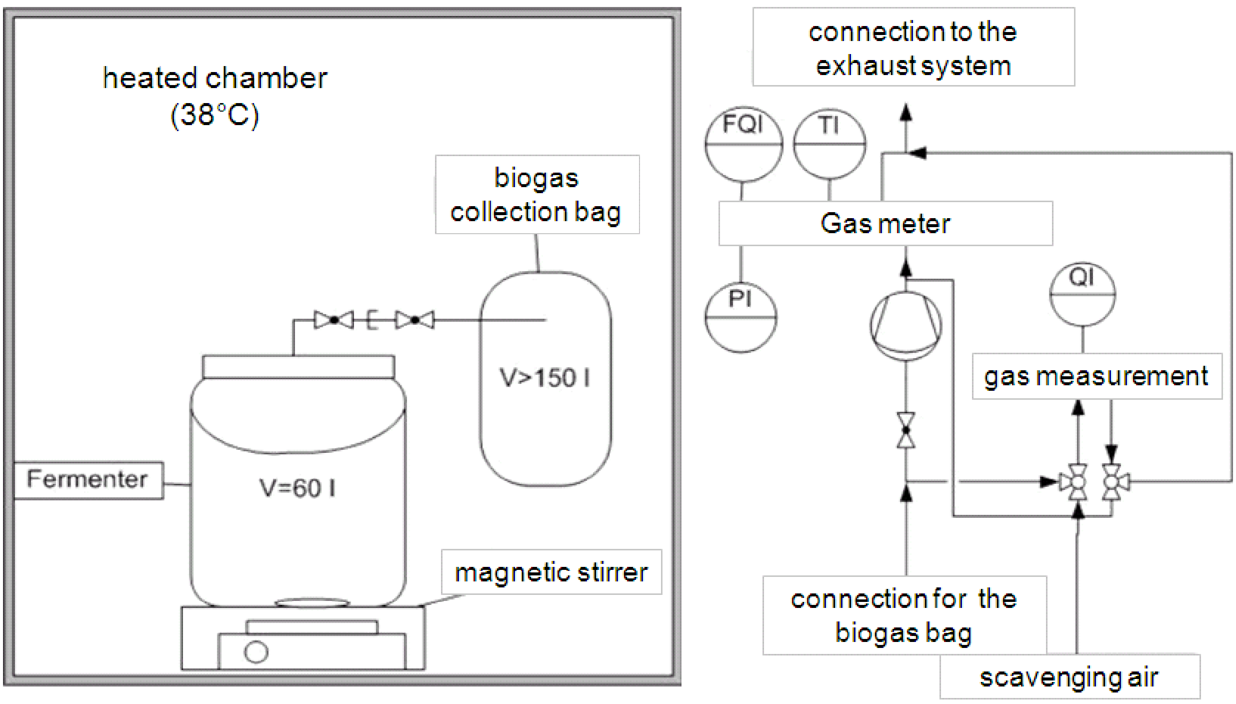

Figure 1. Scheme of the test arrangement for the biogas and methane yield.

Digested sludge from a municipal sewage plant is used as inoculum. The digestion is carried out under mesophilic conditions (38 °C) for a duration time of 30 days. Gas yields are converted to standard conditions (0 °C; 101.3 kPa).

2.3.3 Upper calorific value according to German Standard DIN 51900-1

The upper calorific value is measured using a bomb calorimeter type Parr Instrument 4600 under isoperibol test routine.

2.3.4 Effects on the biogas and methane yield - Activity Test

The application of organic waste fractions in commercial biogas plants is connected with risks due to potentially inhibiting effects by e.g. heavy metals or other pollutions. Thus, additionally to batch tests, activity tests are carried out (Figure 2). The principle of the "Activity Test", developed at the University of Rostock, is measuring the pressure increase at constant temperature and constant volume at high temporal resolution (30 minutes). The test is carried out in 500 ml glass vessels under mesophilic conditions (38 °C). The kinetics of biogas production under standardized conditions is recorded by using a defined synthetic substrate with a quantified gas yield (Engler et al., 2010). The measured amount of biogas is referred to the synthetic substrate's theoretically maximum gas yield according to BUSWELL (1952).

Replications with adding of potentially inhibiting substances (e.g. biowaste) in different concentrations are carried out simultaneously. The comparison of the different biogas kinetics allows the detection of inhibition effects resp. the limiting concentration of the tested inhibiting substances.

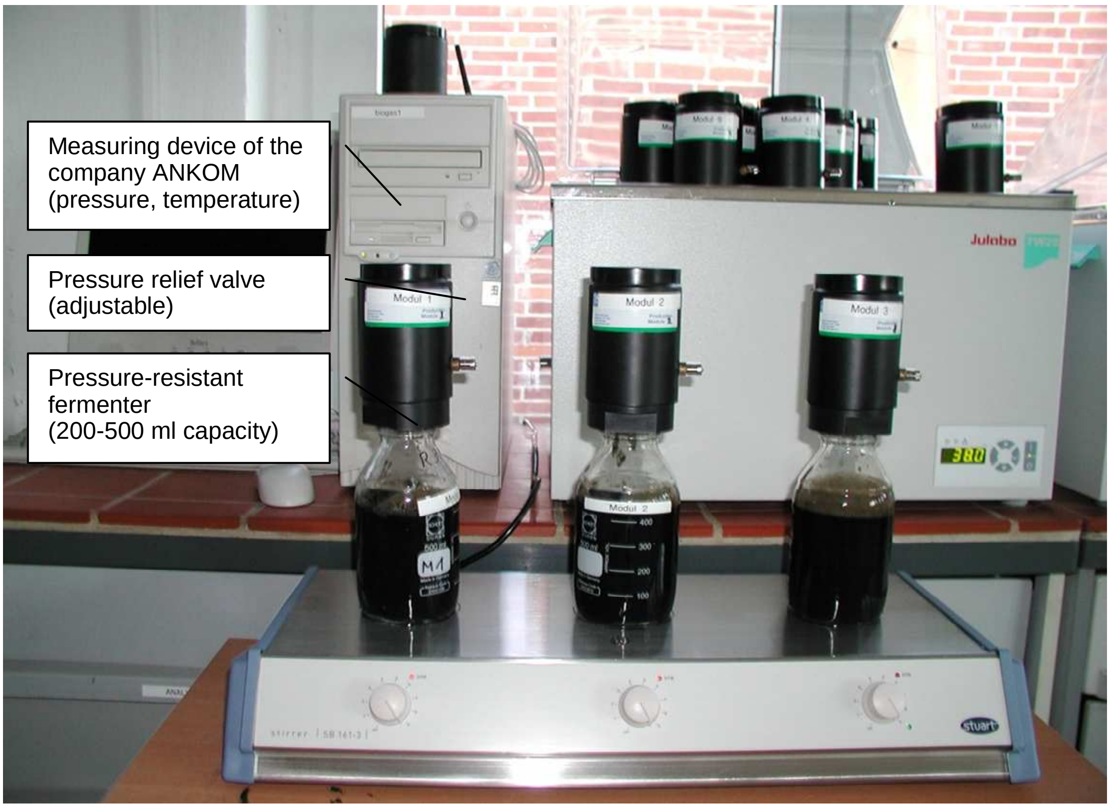

Figure 2. One module of the "Activity Test" arrangement.

The combination of the batch test for estimating the biogas yield and the activity test to identify potentially inhibiting effects, allows a reliable estimation of the energetically potential of e.g. biowaste.

Furthermore a high level on safety can be provided concerning the use of biowaste as co-substrate in anaerobic digestion processes. The analysis of the heavy metals will support the interpretation of the results.

3. RESULTS

3.1 Organic shares of the MSW

Compared with other studies, the identified organic content in MSW is relatively high, even if only the unpacked kitchen and the garden waste considered together. On average, in spring the organic content was 44.6%, sorted by hand (unpacked kitchen waste and garden waste: 37.1%) and 37.3% at the machanically summer sorting, based on fresh mass. The organic part of the summer sorting was even higher, since the shares were in the plastic fraction, which was not analyzed further. The spring sorting showed the trend of increases organic share from territory 1 to 5, this tendency was not observed in the summer sorting. Also based on the fractions unpackaged kitchen waste, packaged kitchen waste, garden wasteand other organic substances, this tendence were not unique.

3.2 Dry matter and dry organic matter of the MSW-Organic

A correlation between organic dry substance content and the various territories could not be found in previous studies. Obviously was the lower content of water and the organic dry substance of the mechanical summer sorting (table 4 to table 6), but this is due not only to the actual waste composition but also on the type of sorting. However, the decomposed organic matter was much stronger than in the spring sorting. The distinction between kitchen and garden waste, however, was no longer possible. In an ordinary hand sorting of the organic fraction, significant amounts of plastics, minerals and glass were sorted.

Table 3 - Organic shares (in % of the FM) in the MSW of the territory types in the investigated region - county NWM, Germany.

Territory type	*Spring sorting [%]*					*Summer sorting [%]*
	unpackaged kitchen waste	*packaged kitchen waste*	*garden waste*	*other organic substances*	*total*	*organic matter*
1 small village	28.9	3.6	6.1	0.9	39.5	40.5
2 village	28.4	6.6	2.4	2.7	40.0	
3 small town	37.2	4.5	2.6	0.8	45.1	36.9
4 district town - periphery	38.3	5.0	5.0	2.7	51.0	35.7
5 district town - city	22.5	5.9	13.9	5.3	47.6	36.1
average	31.1	5.1	6.0	2.5	44.6	37.3

FM=fresh matter

The organic dry substance content of the unpacked kitchen waste and the garden waste (spring sorting) showed no dependence on the territory (table 4 and table 5). The summer sorting showed the trend of a decrease of the organic dry substance content in the MSW with a denser population (table 6).

Table 4 - Dry matter and dry organic matter content of the fraction "unpacked kitchen waste" of the manually spring sorting of the MSW (in % of the FM) related to the territory types.

Unpackaged kitchen waste					
Territory types	*Description*	*Water content* %	*Dry substance content* %	*Organic dry substance content* %	*n*
1+2	village	69.63	30.37	43.42	3
3	small town	70.00	30.00	48.10	9
4	district town - periphery	67.58	32.42	49.84	5
5	district town - city	65.93	34.07	44.34	3
	average	68.29	31.71	46.42	5

Table 5 - Dry matter and dry organic matter content of the fraction "garden waste" of the manually spring sorting of the MSW (in % of the FM) related to the territory types.

Garden waste					
Territory types	*Description*	*Water content* %	*Dry substance content* %	*Organic dry substance content* %	*n*
1+2	village	38.16	61.84	62.86	3
3	small town	81.21	18.79	49.20	3
4	district town - periphery	62.74	37.26	33.76	3
5	district town - city	53.59	46.41	56.00	3
	average	58.92	41.08	50.46	3

Table 6 - Dry matter and dry organic matter content of the organic fraction of MSW, machanically summer sorting (in % FM) related to the territory types.

organic share - mechanically sorting					
Territory types	*Description*	*Water content* %	*Dry substance content* %	*Organic dry substance content* %	*n*
1+2	village	46.91	53.09	36.40	3
3	small town	49.36	50.64	37.74	3
4	district town - periphery	49.66	50.34	32.96	3
5	district town - city	50.75	49.25	32.88	3
	average	49.17	50.83	35.00	3

3.3 Biogas and methane yield and bioactivity test

The analysis of these tests is still pending. The results are presented in the lecture during the Venice2010 conference.

3.4 Type and quantity of interfering substances and sorting accuracy of households

The spring-sorting showed that high quantities of plastics (~ 6 %) were included in the residual waste of the investigated households. The largest parts of these plastics were packagings. Plastic recyclables are collected separately in yellow bags in this district. The fact that there is still a considerable amount of plastics in the residual waste shows that people still seem to be uncertain about how to sort their plastic waste. This uncertainty is also reflected in collected quantities of metals (~ 5%) and glasses (~ 6%). Problematic substances like colors, coatings, adhesives, illuminants, batteries and drugs were also collected (~ 1.6%).

Another reason for the inaccurate sorting could be that it is uncomfortable for many people to sort their waste precisely and spend too much time on it.

It should be emphasized that there was mostly hardly recyclable paper (for example paper towels) collected. This suggests that the separate collection of paper and cardboard works well in the investigated households.

4. DISCUSSION

The recent studies showed that the organic in MSW and thus the energy potential by anaerobic digestion from rural areas can be underestimated. The high organic share indicates that all is not of the compostable matter are used for the own compost. It could be deduced a need for separate biowaste collecting. Also the carried out collections (2008) for garden waste have shown that the need exists, outside the own organic waste composting. However, the resonances at a low financial self-involvement for the collection of gardening waste was lower (2009). On the other hand the found problematic substances and the packing materials in the MSW hint at the fact that the current waste separation can be improved through increased publicity. An additional separate collection system for biowaste could be difficult to establish. But experience of other states, however, show that with the introduction of separate collection of organic waste in small towns quite a high bio-waste collection rate and good quality can be achieved (Kern, 2009). The problematic substances found in MSW like drugs or chemicals might the energy recovery of the Organic in the MSW by anaerobic digestion more difficult. In rural areas, due to the settlement and the related transport, combined solutions needed to exploit the existing potential, whereby different recycling methods - own composting, combination of anaerobic digestion and composting of separate collected biowaste and the anaerobic digestion stage in a mechanical-biological treatment plant for MSW- side by side are possible in rural areas.

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REFERENCES

AWP M-V (2008) Abfallwirtschaftsplan Mecklenburg-Vorpommern 2008. Ministerium für Wirtschaft, Arbeit und Tourismus, Mecklenburg-Vorpommern, Germany, April 2008.

BMU (2009). Renewable energy sources in figures - national and international development, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), Germany, June 2009.

Buswell, A.M. & Mueller, H.F. (1952): Mechanism of Methane Fermentation. Industrial and Engineering Chemistry, 44 (3), 550-552.

DAZ M-V (2009) Daten zur Abfallwirtschaft Mecklenburg-Vorpommern 2008. Materialien zur Umwelt 2009, Heft 3, Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern, Germany, September 2009.

Engler, N.; Schiffner, M.; Fritz, T.; Nelles, M. (2010) Rostocker Aktivitäts- und GRW-Biogasertragstest – Einsatz zur Optimierung von Abfallvergärungsanlagen. Bioactivity test and GRW biogas yield test methods for optimizing biogas plants for anaerobic digestion of bio-waste (in German), in: Müll & Abfall 3/2010, 113-117.

Faulstich, M., Greiff, K. B. (2008) Klimaschutz durch Biomasse. Ergebnisse des SRU Sondergutachtens 2007. Zeitschrift für Umweltschutz und Schadstoff-Forschung 21 UWSF (3), 161-169.

Kern, M.; Raussen, T. (2009) Optimierte stoffliche und energetischen Bioabfallverwertung, Conference Proceedings of the Bio- und Sekundärrohstoffverwertung IV, Fachbuchreihe Abfall-Wirtschaft des Witzenhausen-Instituts für Abfall, Umwelt und Energie, ISBN : 978-3-928673-54-9, 349-369.

Kern, M.; Raussen, T. (2006) Energiepotential von Bio- und Grünabfall. In: BILITEWSKI, B.; WERNER, P.; STEGMANN, R. et al. (Hrsg.): Beiträge zu Abfallwirtschaft/Altlasten, Band 46, Dresden : Eigenverlag des Forums für Abfallwirtschaft und Altlasten e.V., 2006, 141-158.

Nelles, M.; Engler, N.; Morscheck, G.; Schüch, A. (2009) Energie aus Abfall- und Anbaubiomasse - Potenziale, Verwertungsoptionen und aktuelle Entwicklungen, Conference Proceedings of the 11th Münsteraner Abfallwirtschaftstage 10.-11.02.2009, Münster, Germany, 113-120.

Ocik, M.; Nelles, M.; Morscheck, G.; Schüch, A. (2008) Stand und Perspektiven der energetischen Verwertung von organischen Abfällen und Reststoffen in Mecklenburg-Vorpommern, in: Conference Proccedings of the 2. Rostocker Bioenergieforum 29.-30.10.2008, Rostock, Germany, 29-42.

REN21 (2009) Renewable Energy Policy Network for the 21stCentury Global Status Report: 2009 Update (Paris: REN21 Secretariat)

Land Statistical Office MV (2009) Statistische Berichte, Bevölkerungsstand der Kreise, Ämter und Gemeinden in Mecklenburg-Vorpommern, 31.12.2009, Hrsg.: Statistisches Amt Mecklenburg-Vorpommern.

Scholwin, F.; Nelles, M. (2009) Biogastechnologie in Deutschland, Status und Optimierungspotenziale. (in German), in: Müll & Abfall 5/2009, 228-232.

VDI 4630 (2006) Vergärung organischer Stoffe, VDI-Gesellschaft Energietechnik; Fachausschuss Regenerative Energietechnik; Verein Deutscher Ingenieure, Düsseldorf, Germany.

Weiland, P. (2001) Grundlagen der Mathangärung-Biologie und Substrate; in: VDI-Berichte 1620; VDI-Verlag GmbH; Düsseldorf, Germany, 19-32.