Biogenious Waste to Energy – Challenges and Solutions

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Abstract: In the year 2008 the energy consumption of the rapidly industrializing non-OECD economies (including China) even surpassed the OECD consumption for the first time. Worldwide biomass covers about 10 to 13% of the total energy demand and is an important energy system component in developing countries. In some of the developing countries the share of bioenergy is above 90%, since there are no other options for energy supply. Currently the rising interest in bioenergy is also forced by the climate protection goals. Today about 70% of the total share of renewable energy sources in Germany is covered by biomass. The technical potential of bioenergy is estimated to cover 10 to 15% of the primary energy consumption in 2030. The energetic utilization of huge unutilized resources, such as bio-waste and biodegradable residues can help to meet the rising energy consumption. For example, in consideration of ecological requirements about 100 million Mg of this waste and residues are energetic usable and could supply 4 to 5% of the national primary energy consumption in Germany (Faulstich and Greiff 2007). Various technologies are available for the conditioning and conversion of solid biomass to produce solid, liquid or gaseous biogenic fuels. To support climate protection and to help to secure the energy supply bioenergy can contribute a relevant share to the total energy mix.

Key words: Bioenergy, renewable energy, biogas, organic waste and residues.

Introduction

Due to the worldwide continuously increasing population and industrialization the global energy demand is constantly growing. In the year 2008 the energy consumption of the rapidly industrializing non-OECD (Organization for Economic Co-Operation and Development) economies, including China, even surpassed the OECD consumption. Beneffited by government support the use of renewable fuels increased continuously in the last years. Thereby biomass is the oldest energy source of mankind. Worldwide biomass covers about 10 to 13% of the total energy demand and is an important energy system component in developing countries. In some of the developing countries the share of bioenergy is above 90%, since there are no other alternatives for energy supply.

A possible solution to balance economical, ecological and social aspects in rural areas is the utilization of regional biomass to cover the energetic demand of bioenergy villages or bioenergy regions. The idea to supply the energy demand with regional/local resources is older than the current climate protection discussions [1].

In the middle-term 10% of the global energy demand could be covered by sustainable bioenergy made from biogenous residues and bioenergy crops. About 25% of the worldwide bioenergy potential is located in Latin America, each 15% in sub-Saharan Africa, Europe, North America and China and also 6% in India [2].

In 2010 the total share of renewable energy sources covered 11% and biomas covered 7.9% of total final energy consumption in Germany, 4.8 TWh electric and 11.9 TWh thermal from bio waste! At the moment the share of bioenergy in renewable energies is about 71% ([3]; Figure 1 and 2).

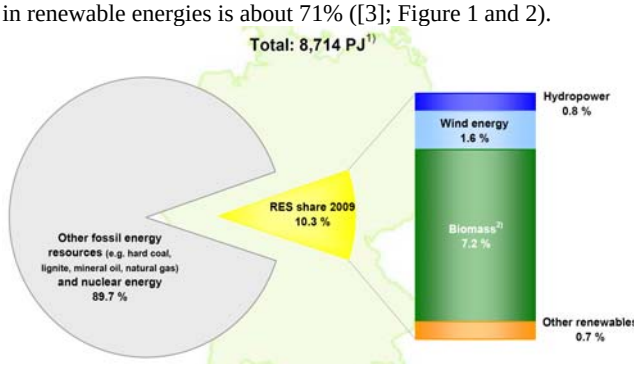

Figure 1. Shares of renewable energy sources among total final energy consumption in Germany in 2009 [3].

Electricity		
Hydropower	[TWh] = (1 billion kWh)	19.1
Wind energy		38.6
Biomass (total)		30.3
therefrom:		
solid biomass		*11.4*
liquid biomass		*2.0*
biogas		*10.8*
sewage gas		*1.1*
landfill gas		*0.8*
biogenic share of waste		*4.3*
Photovoltaics		6.6
Geothermal energy		0.019
Total electricity		94.6

Heat		
Biomass (total)	[TWh] = (1 billion kWh)	110.1
therefrom:		
solid biomass		*86.7*
liquid biomass		*4.6*
biogas		*6.5*
sewage gas		*1.1*
landfill gas		*0.4*
biogenic share of waste		*10.9*
Solar thermal energy		4.7
Deep geothermal energy		0.3
Near surface geothermal energy		4.6
Total heat		119.8

Biogenic fuels		
Biodiesel (approx. 2.5 mill. t)	[TWh] = (1 billion kWh)	26.0
Vegetable oil (approx. 0.1 mill. t)		1.0
Bioethanol (approx. 0.9 mill. t)		6.7
Biogenic fuels (total)		33.8

Total final energy from renewable energy sources	248.1

Figure 2. Contribution of renewable energy sources to energy supply in Germany in 2009 [3].

Thus bioenergy is the most important renewable resource in Germany. The big share of unutilized biomaterial resources can help to meet the rising energy consumption. Especially the energetic value of biogenic waste and residuals from households, industry and agriculture is not to be underestimated. The increasing interest in bioenergy is also forced by the climate protection goals.

The relationship between the concentration of CO_2 in the atmosphere and the continuous global temperature increase shall be deemed to be proven [4]. Thus, the global greenhouse gas emissions must be reduced to mitigate global warming. Measures to achieve this are: energy saving, energy efficiency enhancement across-the-board and the substitution of fossil fuels by renewable energies. In January 2008, the Europe Union decided to reduce the greenhouse gas emissions at least 20 % and to increase the contribution of renewable energies in the total energy consumption up to 20%. According to the ambitious aims of the German Federal Government the CO_2 emissions are to be decreased by 40% (compared to 1990) and the quota of the renewable energies are to be increased to 14% in the heating sector, up to 30% in the electricity sector and about 10% in the transport sector until 2020 [5].

The use of biomass as an energy resource is an essential issue in order to achieve these goals. Currently in Germany (and worldwide) the development of the utilization of biomass as an energy resource is very dynamic. The technical bioenergy potential of Germany is estimated to be able to cover 10 to 15% of the primary energy consumption up to the year 2030 [6].

The reason for the fast development in Germany and Europe are the increasing commodity prices (especially in 2008) and the limited fossil energy resources as well as the policy guidelines of the EU to protect climate and resources.

Energetic use of biomass in Germany

Energy made from biomass or short called bioenergy is the main energy resource of the renewable energies. Figure 3 illustrated how biomass can be converted into different types of biogenic fuels/resources.

Utilization of Solid bioenergy sources

There are different pathways to utilize the energy of waste. In anaerobic digesters biogas can be produced out of the digestible organic fraction (no wood, no lignin). This biogas is used to be burned in motors or turbines to produce electricity (and heat).

It is also possible to use inflammable wastes in different combustion plants. Unfortunately today's world wide main "use" is the **landfilling** of organic waste to produce landfill gas.

1.96 million tons of **sewage sludge** dry mass were produced in Germany in 2009. 30% were used as fertiliser in the agricultural sector, 53% were incinerated and the remaining share was used for landscape building [7]. Most of the waste water treatment plants have digesters to produce sewage gas.

In 2008 the Germans collected approx. 8.7 million Mg **at source separated bio waste** (from organic waste collection bins and organic waste from gardens and parks) [7]. In Germany there exist about 950 compost plants and 100 biogas plants for the treatment of bio waste [8]. From the ecological point of view (greenhouse gas balance) the combination of anaerobic digestion and composting is to be favored compared to a pure composting facility (Figure 4). Germany will increasingly utilize more and more bio waste to produce biogas and electric energy.

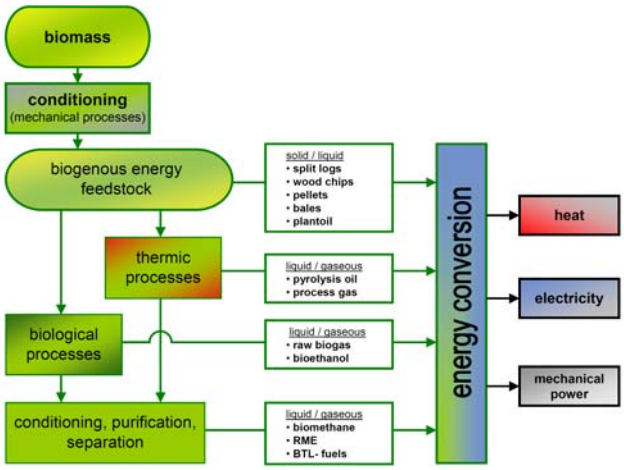

Figure 3. Options for energy supply by utilization of biomass.

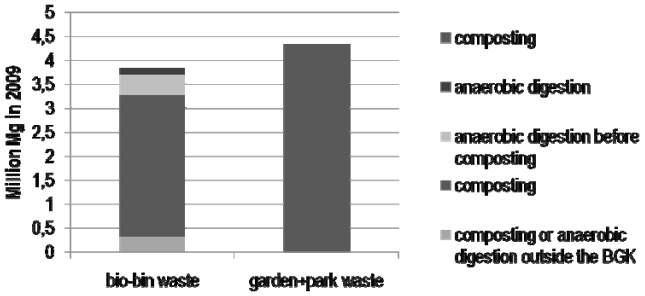

Figure 4. Current utilization of bio waste in Germany [8].

In addition to household waste it is also necessary to use waste wood from different sources (including waste wood in bulky waste). At first this includes the use as a "new" raw material and secondly the use as an energy source.

Gaseous bioenergy sources

Biogas can be produced from a very broad variety of organic substrates; from wastes and renewable resources. The question if a biomass source can be used for biogas production is answered by its anaerobic degradability (fermentation - anaerobic digestion by methane bacteria). Electricity from biogas reduces the demand for fossil fuels and reduces greenhouse gas emissions connected with fossil energy supply systems.

Waste can be an important energy source and the use and recycling of wastes instead of landfilling can reduce the greenhouse gas emissions!

Internationally the main biomass sources are sewage sludge and organic wastes from agriculture (e.g. excrements from animal farming, residues from processing of agricultural products). Also at source collected bio wastes from households and the organic fraction of the residual waste can be used as input material for digesters (Figure 5). But in this case (using parts of residual waste) the use of the digestate cannot be reused in agricultural food production!

Table 1. Some organic waste sources and possibilities of use.

Waste	**Possibilities of adequate use**	**Possibilities of use**
at source collected bio wastes	composting, digestion,	combustion
organic waste in the residual waste	waste incineration; mechanical-biological treatment	landfilling
sewage sludge	digestion, composting; incineration	
organic wastes from agriculture and residues from processing of agricultural products	digestion, composting	
Waste wood	combustion	

Table 2. Composition of residual waste from private households (Germany and P.R. China).

	Average waste composition Germany (Dehoust et al. 2010)	Sorting Analysis Hefei, P.R. China
Organic material	22.5-38.3%	77.4%
Middle fraction	14.2%	
Wood	1.2-2.1%	0.1%
Textiles	2.6-4.9%	0.8%
Minerals	2.8-5.9%	10.0%
Composites	3.3-7.0%	
Pollutants	0.4-0.6%	
Substances n.o.s.	1.1-10.6%	
Fine fraction < 8 mm	10.9-14.7%	
Ferrous/NF metals	2.4-3.8%	0.1%
PBC	7.7-14.8%	2.3%
Glass	4.4-6.9%	1.4%
Plastics	5.8-9.2%	6.1%
Nappies	5.5-14.7%	1.9
Checksum	100%	100%

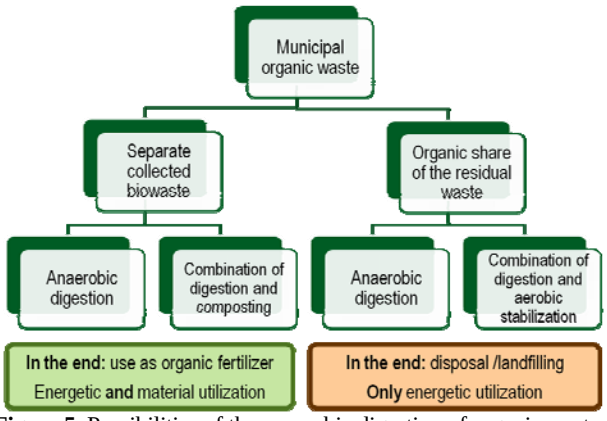

Figure 5. Possibilities of the anaerobic digestion of organic waste.

Additionally high importance has to be paid to landfill gas production and utilization. In this case the organic waste in a landfill is the biogas source, with all the consequences, especially for the climate! Worldwide landfilling of un-treated waste is the main way to handle municipal solid wastes (MSW). MSW contains a lot of bio-waste. Because of the anaerobic decomposition of the organic waste in the landfills, landfills emit so-called landfill gas, the biogas from the digesting process. The energetic utilization of this greenhouse gas seems to start in more and more countries. In Germany landfilling of untreated wastes in landfills is forbidden! Treatment before landfilling means to stabilize the organic compounds in the waste so that no digestion process can occur! The reason for that is that we learned in the last decades, that it is impossible to catch and use more than 50% of the landfill gas amount. “In the EU 27, the situation is different since approx. 40% of waste in the EU is still landfilled. The landfills give rise to substantial methane emissions: 50 million and 80 million t CO_2-eq per annum” [9].

Current biogas technologies have the highest energetic efficiency per acreage of all available biogenic conversion paths [10-11]. Despite this comparatively low contribution, the gaseous bioenergy sources play an important role in the mix of the renewable energies.

Biogas utilization in Germany

Over the past years the production and utilization of biogas has gained much importance in Germany, essentially caused by the setting of an appropriate energy-economical framework. The revision of the Renewable Energy Sources Act (Act on Granting Priority to Renewable Energy Sources) in the year 2004 and 2009 encouraged investigators with additional economic incentives to generate electricity out of biomass by using natural state biomass and organic waste, innovative technologies and cogeneration of heat and power (combined heat and power CHP). Due to the constantly growing number of biogas plants in Germany, the ratio of the total energy converted out of biogas has increased considerably. However, considering plants fermenting remnants and waste, a clear trend in capacity extension of existing facilities and building larger plants can be noted [12].

In many places it is impossible to extent the running plant concept to larger capacities. Therefore, mainly the existing municipal organic waste fraction is applied to approach full capacity. The growing trend of biogas plants, which do not convert the gas directly into electricity on-site, but rather condition the gas to natural-gas quality to be fed into the local gas grid (by the end of 2008 there were 15 plants, mostly in the renewable resource sector) has also its effect on the waste branch [10].

Biogas – Integration in Waste Treatment Systems

Today there are only about 100 running fermentation plants in Germany, which utilize, next to municipal separate collected organic waste, partly or mainly industrial organic residues. The separate collection of organic and green waste provides the foundation for the recycling and energetic utilization of biogenetic waste. Furthermore, combined treatment concepts, consisting of different fermentation and composting stages, can considerably support climate protection [13]. Here, the specific composting of organic waste has a slight negative climate balance, whereas the optimized combined treatment concept can save about 160 kg of the CO_2-Equivalent per t organic waste. Against this background the biogenetic waste composting plants are to be extended with a further fermentation stage in the next years [12].

In Germany the collection of bio waste works fairly well. But several investigations [9-10] showed that the performance/result can still be improved. But not all bio wastes can be captured by separate collection (Table 2 and 3).

Table 3. Organic share of MSW depending from the territory types [14].

Territory type	April	June	October
	In mass%		
1 small village	39.5	38.9	28.3
2 village	40.0		
3 small town	45.1	34.9	32.0
4 district town - periphery	51.0	39.7	27.3
5 district town - city	47.6	42.4	36.2
average	44.6	39.0	31.0

A newer sorting analysis shows even more organic waste in the total residual waste in Germany [14].

The amount of separate collected bio waste was relatively constant in the last years, whereby the share of garden and park waste is inconsiderable higher than the waste from bio-bins. Although Germanys bio waste system works very well compared to many other European countries the amount of used bio waste has to be increased (intensification of the bio waste collection, reduction of home composting) up to 2015 (Figure 6).

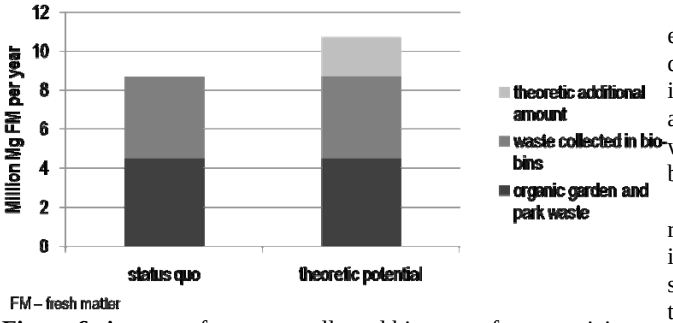

Figure 6. Amount of separate collected bio waste from municipalities in Germany in 2008 (Destatis 2011) and the current theoretically potential [15].

Perspectives of the utilization of biomass as energy resource in Germany

The highest even unexploited energy potential of solid renewable bioenergy sources is seen in wooden biomass and straw. Short-rotation plantations could take on greater significance. Only a marginal increase is to be expected for forest wood. Great potential is attributed to the growing of energy plants [16]. In the middle-term the limited cultivation area will expose the processes with the highest energy efficiency. Therefore, in the future an increase in biogas production for heating, electricity and transport is expected. The utilization of bio waste for energy supply is an ecologically and economically worthwhile option since the biomass will be used repeatedly (figure 7).

Conclusions

Worldwide biomass covers about 10 to 13% of the total energy demand and is an important energy system component in developing countries. In Germany the amount of bioenergy increases constantly. Currently the share of bioenergy covers about 6.6% of the total primary energy consumption. Particularly with regard to the security of energy supply and climate protection bioenergy can contribute a relevant share to the total energy mix.

Bioenergy offers the possibility to harness a domestic, rural-based, low-carbon and sustainable energy source in both industrialized and developing countries. Due to the economic, social and ecological effects bioenergy concepts can contribute to the added value of a region.

The technical potential of domestic biomass in Germany is estimated to cover about 10 to 15% of the total primary energy consumption in 2030. The utilization of bio waste is an ecologically and economically worthwhile option, since the biomass will be used repeatedly.

Hence, one can expect that the biogas technology will be a very important (probably the most important) sector within the supply of renewable energy out of biomass and organic waste. Especially at the global point of view the utilization of the biogenetic waste flow is of great importance.

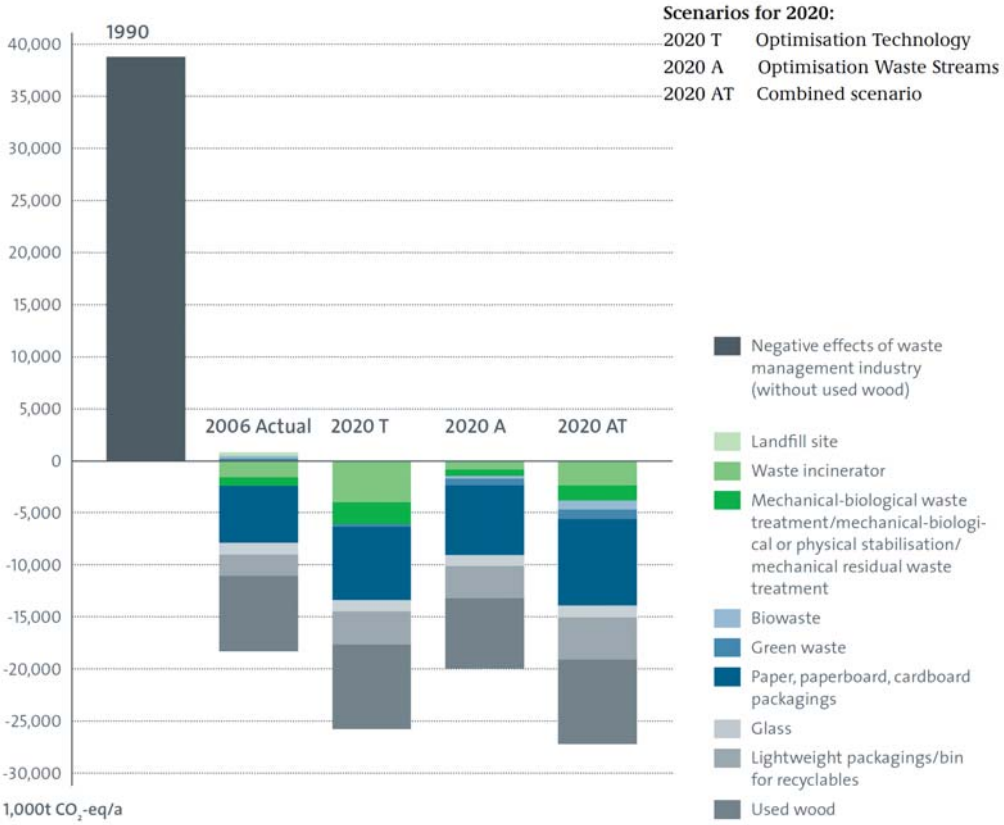

Figure 7. Overall results of standard balance for greenhouse gases in Germany [17].

References

[1] Totter K, Effizienter Klimaschutz, Sicherheit und Beschäftigung durch dezentrale Energieerzeugung und Verwendung, *Conference Proceedings of the 7th Biomassetagung* (2007) am 8. und 9. November 2007, Umwelt Campus Birkenfeld, Germany.

[2] WBGU, *Welt im Wandel: Zukunftsfähige Bioenergie und nachhaltige Landnutzung, Wissenschaftlicher Beirat der Bundesregierung - Globale Umweltveränderungen (WBGU)* (2009) Berlin, Stand: 11.03.2009.

[3] BMU, *Climate relevance of the waste management sector* (2010/2011) German Federal Environment Agency, www.umweltbundesamt.de and http://www.erneuerbare-energien.de

[4] IPCC, (2007) 4. Sachstandsbericht (AR4) des IPCC (2007) über Klimaänderungen, Synthesebericht, Kernaussagen, 17.11.07, Umweltbundesamt (UBA), Berlin.

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

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

[7] Destatis (2010) Federal Statistical Office, Wiesbaden; http://www.destatis.de

[8] BGK, *Bundesgütegemeinschaft Kompost* (2011) Federal CompostQuality Association, http://www.kompost.de/

[9] Dehoust G, Schüler D, Vogt R, Giegrich J, *Climate Protection Potential in the Waste Management Sector Examples: Municipal Waste and Waste Wood; federal ministry of the environment, nature conservation and nuclear safety* (2010) 138 p, Federal Environment Agency.

[10] Nelles M, Scholwin F, Schüch A, Engler N, Bioenergy as a sustainable technology for decentralized and centralized energy systems - Basic Parameters, Current Status in Germany and Outlook, *Tech Monitor May – Jun 2010* (2010) 25 – 30, ISSN 0256-9957, New Dehli, India.

[11] Scholwin F, Nelles M, Biogastechnologie in Deutschland, Status und Optimierungspotenziale, *Müll & Abfall* 41/5 (2009) 228-232.

[12] Scholwin F, Thrän, D, Daniel J, Schreiber K, Witt J, Schumacher B, Jahraus B, Klinski S, Vetter A, Beck J, *Scheftelowitz M, Endbericht zum Anschlussvorhaben zum Monitoring zur Wirkung des novellierten Erneuerbare-Energien-Gesetzes (EEG) auf die Entwicklung der Stromerzeugung aus Biomasse* (2008) Forschungsvorhaben im Auftrag des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit (BMU), Berlin.

[13] Nelles M, Scholwin F, Schüch A, Weinrich S, (2010). Biogas – a Sustainable Technology for Decentralized and Centralized Waste Management Systems, Conference Proceedings to the 3rd Indo-German Conference on Research for Sustainability: Water and Waste Management, Science and Technology – Drivers for a Common Future, New Delhi, India, 3-4 February 2010 (in Press).

[14] Schüch A, Engler N, Lüdecke B, Höfs F, Nelles M, (2010) Potentialities and limits of the anaerobic digestion of municipal solid organic waste in an agrarian region in Germany. In: Proceedings of the VENICE 2010 - Third international symposium on energy from biomass and waste at the 8-11 November 2010 in Venice, Italy ; IWWG International Waste Working Group (Hrsg.): VENICE 2010.

[15] Kern M, Raussen T, Optimierte stoffliche und energetische Bioabfallverwertung, *Bio- und Sekundärrohstoffverwertung IV* (2009) Stofflich - energetisch. Witzenhausen-Institut - Neues aus Forschung und Praxis. Kassel: K. Wiemer, M. Kern. S. 349-369

[16] Faulstich M, Greiff K, Klimaschutz durch Bioenergie?! – Ergebnisse des SRU-Gutachtens 2007, *Conference Proceedings to the 1st Rostocker Bioenergieforum „Bioenergieland Mecklenburg-Vorpommern“ 25. and 25.10.2007* (2007) University of Rostock, Germany, pp. 39-66.

[17] German Federal Environment Agency, Climate relevance of the waste management sector (2011) 12 p, www.umweltbundesamt.de