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Bio-Waste Recycling in Germany – Further Challenges

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Abstract

German biodegradable waste is collected separately, recycled and ecologically and economically used. Compost and digestate are used as organic fertilizer or replace peat in potting soil and plant substrates. The bio-waste recycling may also directly contribute to climate protection if the methane produced during the fermentation is used for energy production. Around the world biodegradable waste in landfills is the main factor for the generation of the greenhouse gas methane.

This environmental impact can be significantly reduced by the separate collection and recycling/use of organic waste. The separate collection of bio-waste is also a precondition for reutilizing of organic matter and nutrients. Only from separately collected bio-wasteit is possible to produce high-quality compost and digestate, which are suitable for agricultural or horticultural use.The separate collection of bio-waste from households affects the amount and composition of the residual waste. By separating bio-waste the remaining amount of waste is reduced up to a third. At the same time the residual waste contains less wet ingredients, which facilitate the waste sorting and makes the treatment in waste incineration plants more effective or even possible.

Both, the recycling of compost and digestate on soils, as well as the energy recovery of bio-waste, contribute to climate protection and resource conservation. The operation of the treatment plants determines how much of the greenhouse gases methane, nitrous oxide and ammonia is released during the process.

Some plant operators need to be awakened and their awareness of climate-relevant emissions from their bio-waste treatment plants has to be raised.Also the amount of collected organic waste should be further reinforced. In 2015 the separate collection of bio-waste has to improve!

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1. Introduction

Germany has implemented a separate collection for waste, household and other kinds of waste, more than twenty years ago. Diverse environmental damages, lack of landfill space and the use of finite resources led in the early 90s to a rethink in waste management. Today, climate change and energy demand are important arguments for the separate collection and utilisation of all kinds of organic wastes. In response to the EU's waste framework directive, the Waste Management Act of 2012 (KrWG) in § 11 paragraph 1 obligates waste producers and mandated waste management authorities to collect bio-waste separately at the latest as of January 1st 2015. The term "bio-waste" in § 3 KrWG comprises yard, park, and landscape management waste as well as food and kitchen waste. The requirement in the Waste Management Act (KrWG) to collect bio-waste separately (§ 11/2 KrWG) is concretised in the Bio-waste Ordinance (BioAbfV).

This article tries to discuss all kind of organic waste but is focused on the bio-waste from private households that is collected by using bio-waste bins. Wastes collected through bio-waste bins, especially food, kitchen and yard waste, are monitored according to the European Waste Catalogue (The European Commission 2014.) laid down in the Commission Decision 94/3/EC and the German waste index regulation (AVV) under the waste classification key 200308 (biodegradable kitchen and canteen waste, with animal residues) (Deutsche Bundesregierung 2001).

The German Bio-waste Ordinance (Ordinance on the Recovery of Bio-waste on Land used for Agricultural, Silvicultural and Horticultural Purposes) (Deutsche Bundesregierung 2013) defined bio-waste in general:

Waste of animal or plant origin or from fungal materials for recovery purposes, which can be degraded by microorganisms, soil-borne organisms or enzymes, including wastes for recovery purposes with high organic content of animal or plant origin or fungal materials (details in Annex 1 Bio-waste Ordinance)

This article will use:

- Bio-waste (collected in bins): separately collected (in bio-waste bins or bags) food and kitchen waste, and yard waste from private households.
- Green waste: Separately collected yard waste from private households, and waste generated in municipal parks and in landscape management (Krause et al. 2014).
- "Organic waste" is used for all kinds of biodegradable wastes.

For the treatment of separate collected bio-waste (composting and digestion) the important laws are given with (BGK 2014):

Bio-waste Ordinance (BioAbfV 1998, revised in 2012): The amended Bio-waste Ordinance (BioAbfV) of 2012 covers the application of treated and untreated bio-wastes and mixtures on land which is used for agricultural, silvicultural and horticultural purposes. It also covers suitable raw materials, quality and hygiene requirements, and treatment and investigations of such bio-wastes and mixtures. The Bio-waste Ordinance regulates – from a precautionary perspective – the waste side (e.g. heavy metals) of the application, whereas the fertiliser law regulates the nutrient part.

Fertiliser Law (DüV 2007): Gives the frame for the good code of practice of fertilising and shows special requirements for organic fertilisers. It includes the restrictions for the application of fertilisers with essential nitrogen contents in winter periods.

Fertiliser Ordinance (DüMV 2012): Compost from biodegradable waste is subject to the fertiliser ordinance as a secondary raw material fertiliser (or seldom as soil improving agent). A declaration of the fertiliser type, raw material, nutrients and other product properties is obligatory. Threshold values for contaminants like PFT, PCCD or dl-PCB, included in the Fertiliser Ordinance are obligatory for compost and digestate, too.

Federal Soil Protection Law (BBodSchG 1998/BBodSchV 1999): Ensures the soil function and gives among others precautionary requirements for the contamination of soils. The soil protection law is relevant for the application of compost and digestate for landscaping and recultivation.

2. What to do with organic waste?

Organic materials which the holder discards or intends or is required to discard become organic waste. The organic waste can be disposed of or used in different ways. The type of disposal determines the possibilities of utilization.

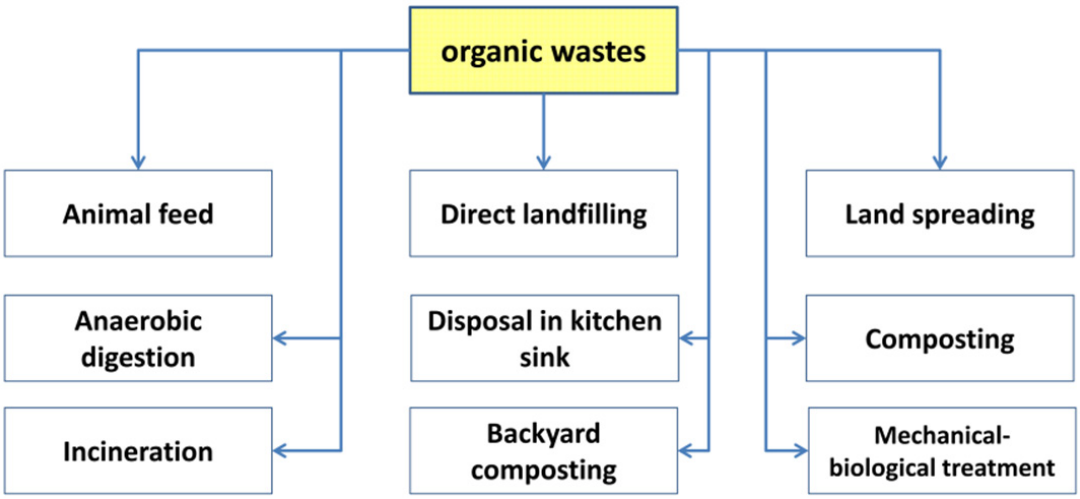


Fig. 1."Treatment" options of organic wastes (not all practised in Germany)

3. Bio-waste recycling is climate protection

The federal government targets to reduce the German emissions of greenhouse gases by 40 percent compared to 1990 levels until 2020. This objective can only be achieved by a sustainable energy economy - saving energy, renewable energy generation and efficient use of energy.

What could the waste industry additionally do, to achieve the resource, energy and climate objectives in the future?

In particular, the use of organic waste can contribute to achieving the objectives. Today waste management saves annually about 56 million tons of carbon dioxide equivalent compared to 1990 and contributes significantly to the achievement of the climate protection goals. This has been achieved through the waste separation in the households, which is established in Germany since more than two decades. The separate collection of bio-waste and green waste takes a leading position in comparison across Europe.

The share of renewable energy (such as by energy crops) in energy production should be increased further. The cultivation of energy crops is however in competition with food and feed production. For this reason the combined energy and material use of bio-waste and green waste is of particular interest.

A sustainable management of biogenic material flow combined material and energy recovery paths (nutrient and carbon recycling, energy supply, reducing carbon dioxide emissions by replacing fossil fuels, reducing the peat demand and lower treatment costs with extended regional added value).

Important questions are:

- what can be done to optimize collection and recycling of bio-waste
- which additionally exploitable potential exists
- how much work is required
- which benefits in relation to expenses is achieved.

The potential benefits of all biodegradable wastes should be utilized as much as possible and for this purpose the optimal combination of treatment methods has to be used.

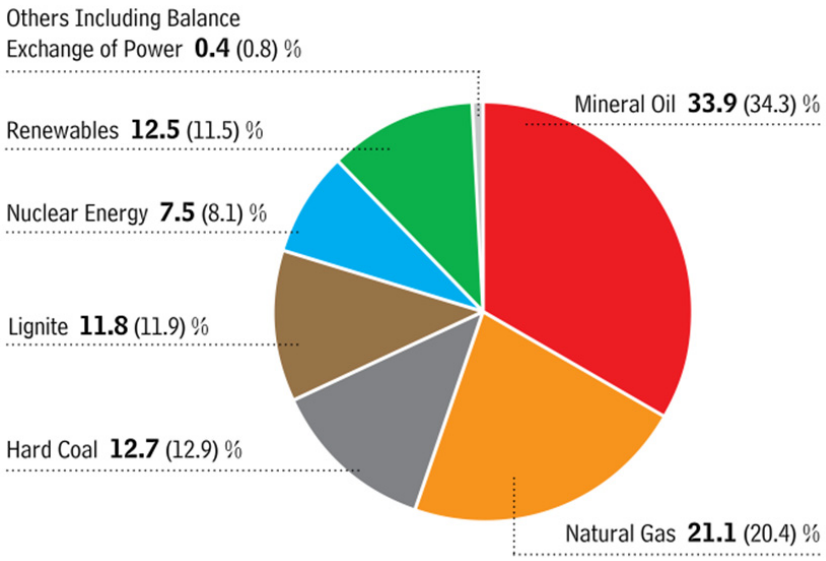
Annually around 100 million tons of biodegradable wastes from, for example, forestry, agriculture or wastewater and waste management, arise nationwide. Of these, approximately 65 percent are technically and ecologically sensible usable, a potential of four to five percent of primary energy demand in Germany. Realising this residue potential is a significant part of the municipality's responsibility.

4. Ecological aspects of composting and anaerobic digestion of organic wastes

The utilization of organic waste reduces the release of greenhouse emissions compared to landfilling or incineration of wet organic waste in waste incineration plants.

The potential environmental benefits of a consistent recovery of bio-waste in Europe could achieve $CO_{2\text{-Eq}}$ savings of up to 50 million tons. The AD of organic waste would reach up to 7% of the overall EU target for renewable energy in 2020. Up to 42% of the bio-fuel target could be attained by the produced biogas. The AD of biodegradable waste is not only successful climate protection policy and independent energy production but also a relevant contribution to the humus formation of agriculturally used soils in Europe. Limited resources, such as raw phosphate, can be protected by the recycling of the plant nutrients in the compost.

Not more than 11.1% of the primary energy consumption comes from renewable energy sources; less than 10% of the renewable energy comes from wastes. In the electricity sector the share of renewable energy climbed to 25.3% of the total (gross) electricity production. Utilisation means composting and anaerobic digestion(AD) of bio-waste or incineration of woody dry green waste. But even these uses emit greenhouse gases. Emissions can be reduced by a good process control and plant construction.



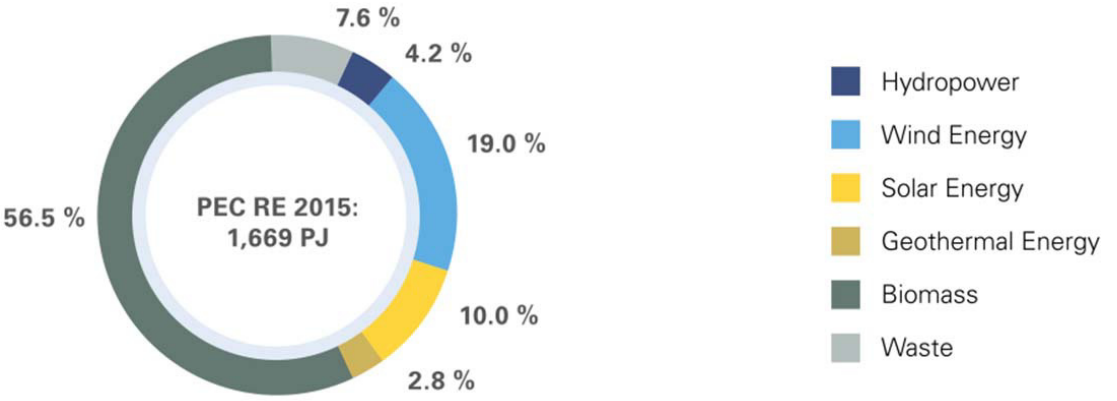


Fig. 2. Share of renewable energy of primary energy consumption in Germany in % 2015(2014) (AGEB 2016)

The formation of greenhouse gases (GHG) as methane (CH_4), nitrous oxide (N_2O), ammonia (NH_3) and non-methane volatile organic compounds (NMVOC) in composting and digestion processes of organicwaste depends primarily on the carbon and nitrogen content in the raw material, the structure as well as the process conditions. “It depends less on the technical standard and procedural features of the treatment plant itself. The anaerobic metabolism product methane occurs also in the aerobic composting processes; the generated amounts depending on the released anaerobic activity and oxygen supply” (Cuhls et al. 2015). It is important that digestion plants use the total potential of the biogas. Tanks and basins with anaerobic activity, e.g. liquid fermentation residue (digestate), should be encapsulated and connected to the biogas network. Slightly with methane contaminated air flows should be used in the combined heat and power unit as combustion air or re-used as process air within the fermentation plant. In order to safely dispose of methane, exhaust air flows with high loads of methane should be combusted. On site existing biomass power stations or other combustion plants contribute to the emission control synergy (Cuhls et al. 2015).

High emissions to the atmosphere result mostly from mistakes in operation.

For the biogas process reasons might be:

- inappropriate feeding system (processes in uncovered storage)

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- inappropriate feeding system (processes in uncovered storage)
- leakage (biogas fermenter, biogas storage, pipes, valves)
- high biogas potential of the digestate (insufficient biodegradation).

In the composting or post-composting (after anaerobic digestion) process, reasons for emissions include:

- unfavourable dimensions of windrows
- insufficient use of strengthening material
- inadequate turning intensity
- high water content
- insufficient air porosity.

In the composting process all of these conditions result in a lack of air (oxygen) supply.

A closed composting process with active ventilation and exhaust gas cleaning enables a process control to reduce emissions. In practice the existing modes of operation often do not aim to reduce emissions of GHG methane and nitrous oxide (Cuhls et al. 2015).

Methane is not or only slightly decomposed in biofilters. A further development of biological processes to remove methane (e.g. in downstream methane oxidation filters) is needed Nitrous oxide is formed within the biofilter by NH_3 conversion and its secondary products (nitrification). Therefore a removal of NH_3 before the ammonia-rich gas reaches the biofilter is necessary. The solution could be acid scrubbers. The product is a dilution of ammonium sulphate, which can be concentrated and recycled as fertilizer. This applies especially to ammonia emissions from AD plants. The process conditions are crucial for the GHG emissions. With regard to the reduction of GHG emissions open windrows as well as closed composting plants (with or without AD) can be improved.

The formation of nitrous oxide can only be suppressed preventive in the biological treatment process (in situ). A subsequent reduction is not possible in any exhaust gas purification (end-of-pipe). Currently there is a lack of technical and operational requirements for a low-emission operation, in particular in order to reduce methane. reatment of organic wastes and bio-waste management reduces the emissions of GHG, but produces also a share of the total GHG emissions. Important are the total greenhouse gas emissions from the treatment process as well as the storage and spreading of compost and digestate in the recycling of bio-waste and green waste. The extrapolation of the greenhouse gas emissions of CH_4 and N_2O and the effective indirect greenhouse gas NH_3 from the operated bio-waste treatment plants (Input about 9 million tons of organic waste per year), including the emissions from the storage and spreading of compost and fermentation products results in a percentage of Germanys total greenhouse gas emissions for methane of 0.591%, nitrous oxide 0.293% and by ammonia of 0.33%.

The contribution of the biological treatment and recycling of bio-waste and green waste based on the sum of total greenhouse gas emissions (CO_2-equivalent) in Germany amounts to 0.066% (Kehres 2015).

5. Separate collection of bio-waste in bins, bags or containers

The waste management system in Germany is carried out in a so-called "dual system". Residual waste and organic waste are in the responsibility of the mandated waste management authorities (public administration, örE) other recyclable household waste fractions are disposed of by private waste management companies. In 2012, the amount of bio-waste separately collected from private households and landscape management of public land in Germany amounted to 9.1 million Mg. A part of 4.3 million Mg of this amount were collected using bio-waste bins and 4.8 million Mg were green waste, collected by the mandated waste management authorities (örE). The population specific average amount of bio-waste collected (in bins or bags) Germany-wide reaches 54 kg/capita/yearand green waste 59kg/capita/year. The collected amounts vary significantly across the German federal states (Krause et al. 2014, see Fig. 3).

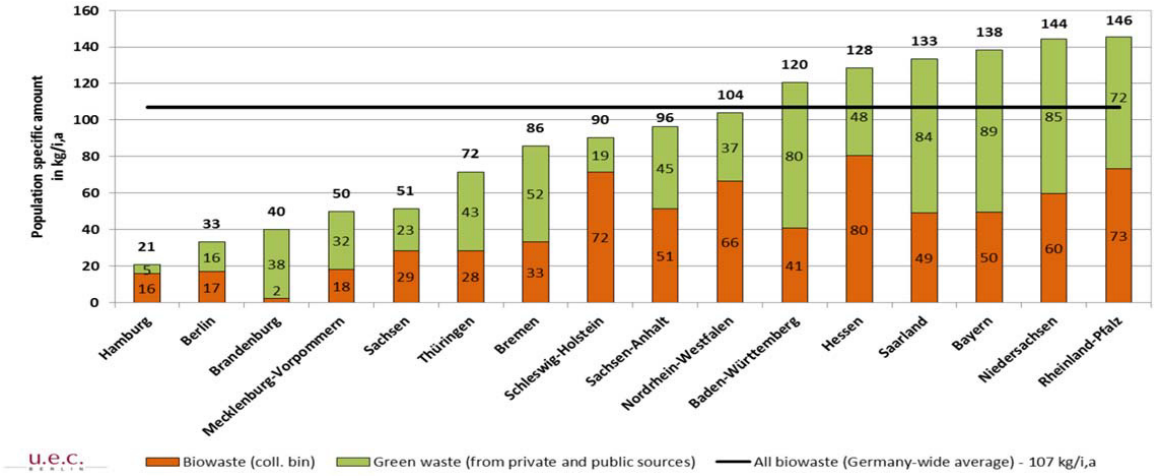

Fig. 3.Separately collected amounts of bio-waste in German states in 2010 (Krause et al. 2014)

The mandated waste management authority can collect bio-waste in a pick-up or drop-off method. The authority has the choice to use bio-waste bins or bags as a collection container.

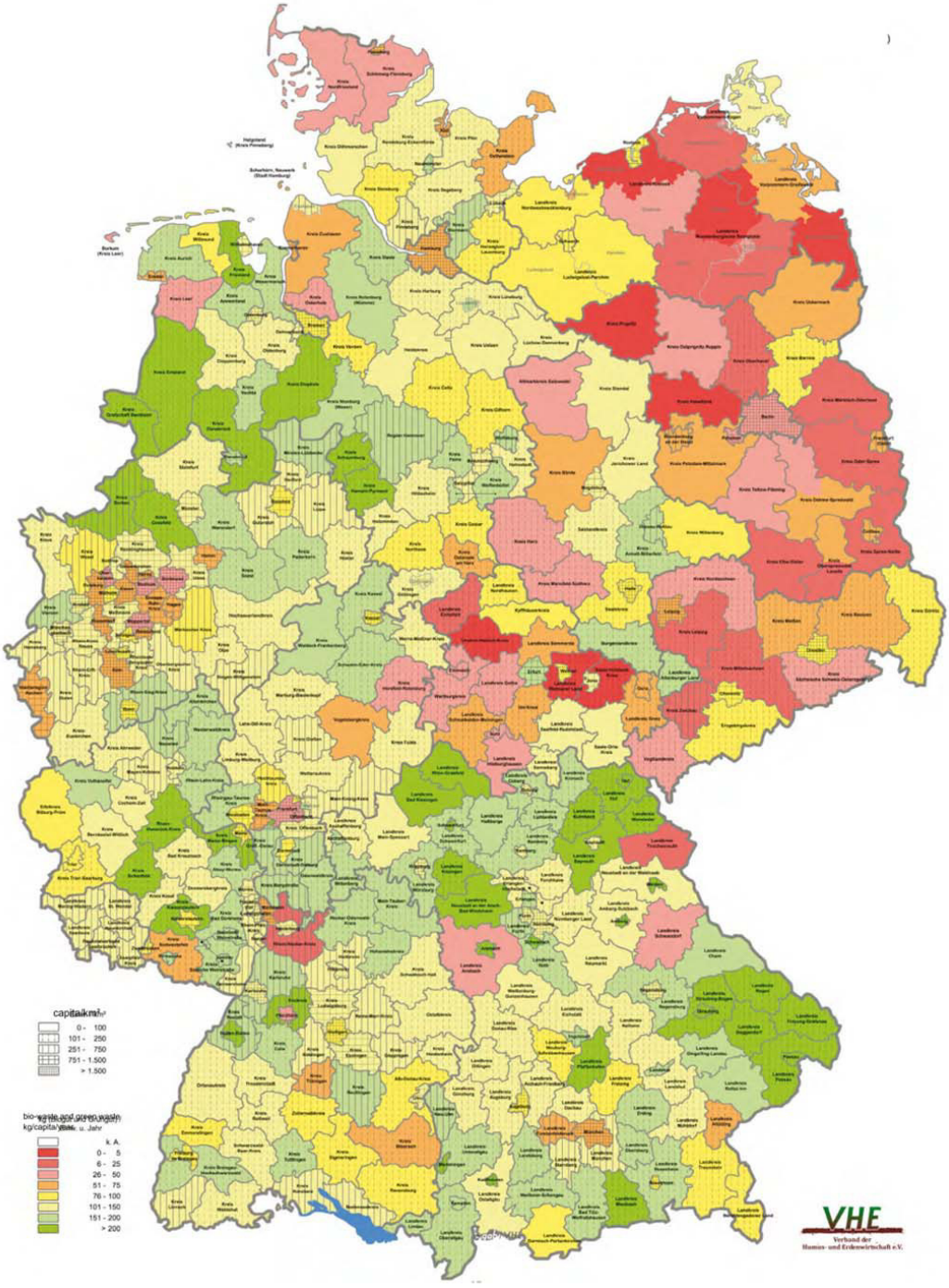

Fig. 4. Population specific amounts of collected in German districts in kg/capita/year (2008 -2011, according availability) (VHE 2012)

Still not every household (waste-producer) in Germany is able to participate in separate bio-waste collection!

In 2010, private households in only 287 districts had access to a comprehensive separate collection system that uses bio-waste bins and is operated by mandated waste management authorities. While 39 districts offered separate collection in some parts of the waste management area, 76 districts offered no bio-waste bin service at all (Oetjen-Dehne et al. 2014).

Separate collection systems for private yard waste, however, are in place in most districts. Only seven districts do not have the possibility to dispose of green waste separately through mandated waste management authorities.In addition to various “bring systems” (green waste collection, green waste containers, mobile collection sites, etc.) and “pick-up systems” (kerbside collection system) for selected green waste (street collection, collection of bags of leaves, collection of Christmas trees, bundles collection etc.) are offered.

A survey among public waste management authorities in 2012 (Krause et al. 2014) revealed that the actual rate of access of private households to separate bio-waste collection using bio-waste bins amounts to roughly 52% Germany-wide. This number increases to 65% in areas of comprehensive separate collection systems. Nearly 40 million people in Germany do not use the bio-waste bin!

As Fig. 4 shows the total amount amounts bio-waste and green waste collected in the different districts ranges from 5 to more than 200 kg/capita.

In 2015 57 to 69 administrative districts will offer no compost bin! The collection of organic waste must be further strengthened. The resource Organic waste must be used more extensive. Only 35% (green waste and bio-waste, 3.4 and 3.9 million tonnes) of the theoretical bio-waste potential (21.1 million tons) has been separate collected by the public waste management authorities in bins, bags or containers in 2010, while roughly 23% (4.8 million tons) were collected with the residual waste.

Another significant amount was disposed of in private backyards composting and in non-recorded private business bio-waste treatment facilities.

As residual waste analyses confirm, normally most organic material contained in residual waste consists of kitchen and food waste. Further separation efforts of residual waste should therefore focus on the separation of kitchen waste from households and gastronomy. The comparison of residual waste composition in areas with and without bio-waste bins shows that already established bio-waste bin collection reduces the amount of residual waste by 15 to 20 kg of organic matter per person and year. Additionally, yard waste is getting into bio-waste bins that would otherwise be individually composted, be illegally disposed of, or get burned. Broadly speaking, 1 kg of organic matter that is getting separated from residual waste will lead waste management authorities to gain 2 kg in yard bio-waste. Oetjen-Dehne et al. (2014) and Krause et al. (2014) describe the bio-waste disposal situation in 2010 by using a bio-waste flow model (Fig. 5).

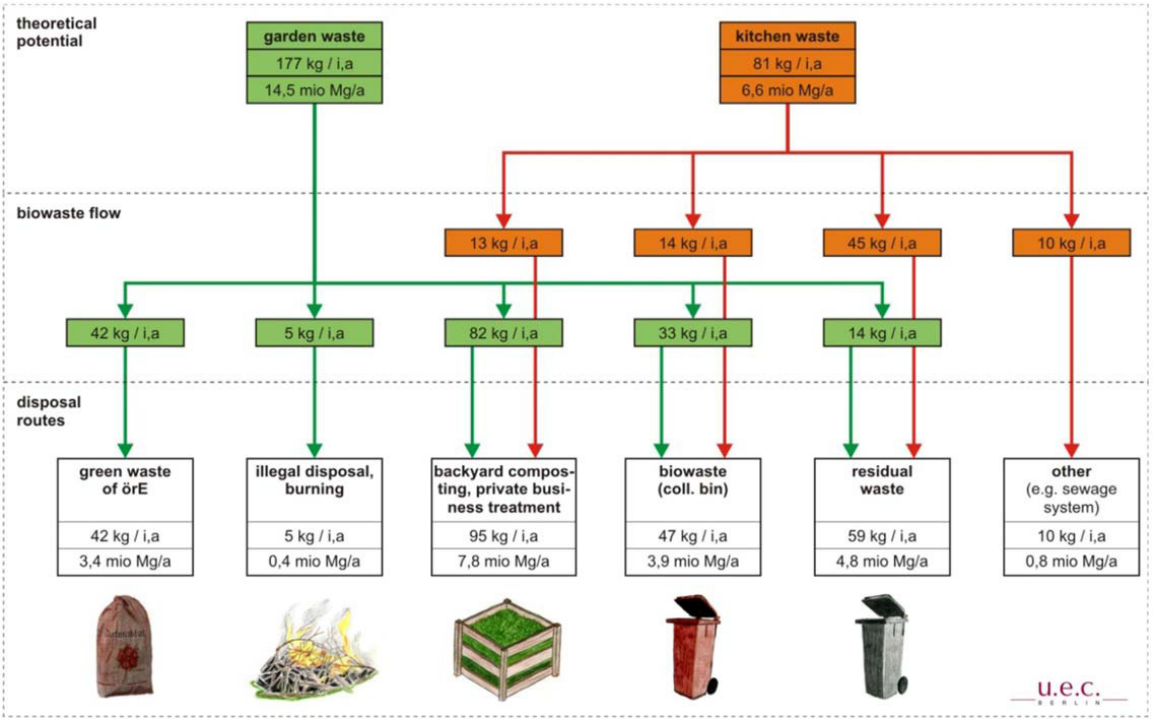

Fig.5.Bio-waste disposal routes of kitchen and yard waste in Germany in 2010 (Krause et al. 2014

Nevertheless, even in optimal separate collection systems and in the case of efficient use of the bio-waste bin, yearly 15 to 20 kg/capita of organic matter will usually go into residual waste, but today 59 kg/capita.

In total 28.4 % (per year: 6 million tons; 74 kg/capita) of the organic waste are not collected separately!

Positive is that per year already 15.1 million tons of organic waste (184 kg/capita) are (collected), treated and used (42 kg/capita green waste; 95 kg/capita back yard composting and private business treatment; 47 kg/capita separate bio bin collection). Which is more than the by the European Union estimated collectable emergence of 150 kg/capita. EU-wide previously only 50 kg/capita organic wastes are collected per year.

The collection and recycling of bio-waste can also be profitable.

Electricity from bio and green waste can be reimbursed according to §27a EEG up to 50 - 75 € per ton. But the substitution effects by material recycling of bio-waste are not promoted. Currently only 5 - 15% of the organic waste is used for the production of biogas. The total potential of fermentable organic waste amounts to 11.7 million tons (Struwe 2010).

6. Ways to increase the collection of bio-waste

In Germany the biological waste treatment looks back to a successful tradition and has become firmly established on an advanced level with about 9 million tons of separately collected organic waste as part of the municipal solid waste (bio-waste in the bio bin and green waste). However, in principle an increase in collection of 2 to 4 million tons is possible.

Basically are two **collecting systems** are available.

Kerbside collection system - householders are encouraged to separate targeted recyclables from their general waste and deposit this at the kerbside for regular collection.

Bring systems - are also known as fixed point systems or drop-off centres, and they comprise large recycling containers in easily accessible places (household waste recycling centres or supermarkets).

The bio bin is part of a kerbside collection system, green waste, especially woody green waste is collected by a bring system.

In response to the EU's waste framework directive, the Waste Management Act of 2012 (KrWG) in § 11 paragraph 1 obligates waste producers and mandated waste management authorities to collect bio-waste separately at the latest as of January 1st 2015.

As outlined in the preceding presentation, improved organic waste collection is necessary.

The introduction or expansion of separate collection of bio-waste in regions without or with only a small level of connection to the organic waste collection is very important.

In areas with separate collection of bio-waste could be offered measures to increase coverage rates and quality of the material flows.

Objectives must be:

- the widespread removal of bio-waste and green waste from the residual waste
- optimizing of material and energy use by separation of organic waste streams for the most appropriate recovery operation.

Among other things the success depends on the following conditions:

- compulsory connection and usage of bio-waste collection systems
- regional structures of the collection area
- waste-fee system (users and pay in proportion of waste amount) for residual waste and bio-waste
- increasing the collection volumes of green waste, better collection system, banning the burning of (woody) green waste
- Better public relations work

Expansion of the separated collection system "Bio bin" only makes sense with high quality recycling of the organic waste (high-quality recycling by material and energetic utilization).

The best recovery can be realized by fermentation (AD) followed by composting of solid fermentation residues (cascade use).

Environmentally sustainable fermentation:

- Except the woody ingredients all the bio-waste is fermented
- Low-emission fermentation (including closed halls, gas-tight Storage of liquid digestate, optimized gas usage)
- Use of heat from the conversion of biogas to electricity!

Although in Germany the bio bin is already successfully introduced, there are not yet connected to the bio-waste collection authorities and people concerns about the bio-waste collection.

The resistances are against the compulsory introduction of bio-waste collection since January 2015.

Separate collection results in higher costs. These costs are acceptable and must to be defrayed by the waste producer.

The backyard composting captures and recycles not enough organic waste. Too much bio-waste is located in the residual waste. More than 100 kg bio-waste is collectable in bio bins even in areas with low population.

In the worldwide comparison the use of bio-waste in Germany is of a good level.

The tasks for the coming years can be summarized as follows:

- All counties and cities (mandated waste management authorities - örE) have to introduce or improve the separate bio-waste collection (bio bin and green waste);
- Possibly higher waste fees are economically viable;
- The share of fermentation (AD) of organic wastes needs to be increased;
- The management of digestate must be improved to reduce the release of greenhouse gases;
- The use of heat from biogas electricity production needs to be increased.

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