Project 'BIN2GRID'

Turning unexploited food waste into biomethane supplied through local filling stations network
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Catalogue of food waste types and energy potential

WP 2 – Task 2.2, D2.2

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Bin2Grid website: www.bin2grid.eu

Content

1 ACKNOWLEDGEMENTS

This report was elaborated in the framework of the Bin2Grid project (Turning unexploited food waste into biomethane supplied through local filling stations network). One of the main objectives of the project is to promote sustainable waste management, especially to link food waste with its energy potential.

Bin2Grid project and its consortium partners strongly support all steps in the waste hierarchy, emphasizing that the prevention and reduction of the food waste should be one of the priorities. Nevertheless, due to the current processes in food and beverage industry and day-to-day activities in the households, it is inevitable that the different waste fractions will be produced. Among them is also food waste, whose human consumption is no longer possible.

The purpose of this report is to provide clear and easily comparable figures of energy potential of different food waste types when it has been already produced. Main characteristics as well as energy potential are provided.

This report is focused on the waste from the households, catering services, as well as food and beverage industry. Wastes from forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood are not included in this report.

The general aim of the Bin2Grid project is to promote sustainable waste management in the target cities: Zagreb, Skopje, Malaga and Paris, thru the implementation of FoodWaste-to-Biofuel concept.

2 GLOSSARY

Anaerobic Digestion (AD)	AD is a natural process in which microorganisms break down organic matter, in the absence of oxygen, into biogas and digestate.
Biogas/Biomethane	A combustible gas derived from decomposing biological waste under anaerobic conditions. Biogas from organic waste normally consists of 50 – 75 Vol. % methane. Upgraded or purified biogas is called “biomethane”. Biomethane has a methane content of >95 vol. %.
Biodegradable waste	Type of waste of which can be broken down, into its base compounds by micro-organisms, regardless of what those compounds may be.
Biowaste	Biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants.
Composting	Biological process under controlled aerobic conditions (requires oxygen). In this process, various microorganisms, including bacteria and fungi, break down organic matter into simpler substances.
EU, EC	European Union, European Commission
FM	Fresh material
Green waste	The organic fraction of the waste stream arising mainly from landscape maintenance and gardening. This waste fraction is usually characterized by higher lignin contents and thus, often used for composting instead of fermentation.
Incineration	Waste treatment that involves the combustion of organic substances contained in waste materials.
MBT	Mechanical and biological treatment of waste.
Substrate	Different types of biomass origin for AD.
Waste hierarchy	Sets the priority order in waste prevention and management legislation and policy: prevention, preparing for re-use, recycling, other recovery, energy recovery and disposal.

3 INTRODUCTION

During the last decades the European Union (EU) has made significant steps towards the promotion and implementation of sustainable waste management. One of them is certainly the resource-efficiency approach in the waste sector, where waste is a resource to be fed back into the economy as a raw material, as the European Commission (EC) highlights in the official documents [1]. One of the conclusion is that much higher priority needs to be given to re-use and recycling of waste.

Having in mind that still large part of the waste is sent to landfills, activities in that direction should be one of the priorities. Treatment of municipal waste in EU is showed in figure 1.

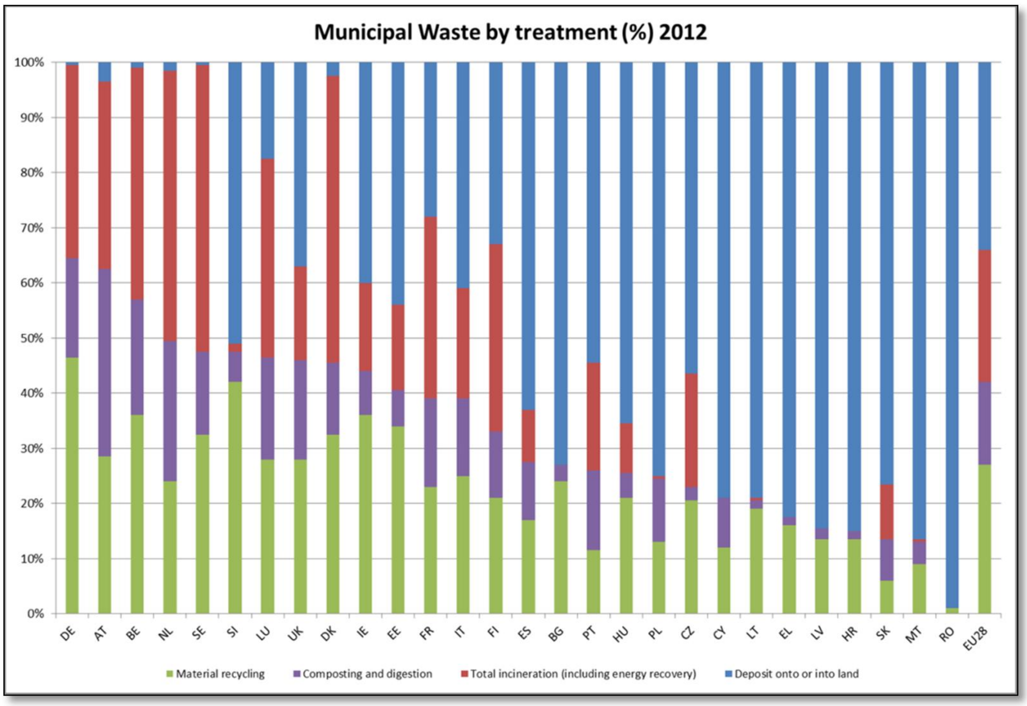

Figure 1. Municipal waste treatment in different EU countries

The biodegradable fraction of the municipal waste represents one of the biggest challenges in order to introduce sustainable waste management. Currently the main environmental threat from biowaste (and other biodegradable waste) is the production of methane from such waste decomposing in landfills, which accounted for some 3% of total greenhouse gas emissions in the EU-15 in 1995. The Landfill Directive[2] obliges Member States to reduce the amount of biodegradable municipal waste that they landfill to 35% of 1995 levels by 2016 (for some countries by 2020) which will significantly reduce this problem (European Commission, 2015)[3].

Because of the different current waste management practices in the Member States (MS) (separate collection, MBT, incineration, landfilling), this obligation will be quite demanding for some EU members. This especially concerns the new EU MS since their current waste management practice is often only landfilling.

The obligation to reduce landfilling of biodegradable waste is mainly related to paper and biowaste since they represent largest portion in overall municipal biodegradable waste.

However, also wood and textiles is defined as biodegradable waste. Different types of municipal biodegradable waste are shown in the figure 2.

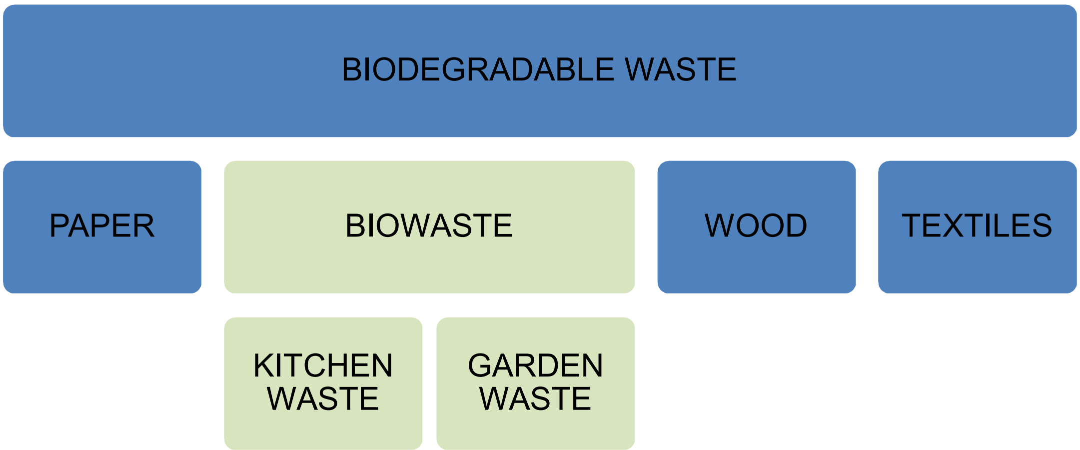

Figure 2. Fractions of the municipal biodegradable waste

Sustainable biowaste management should follow the waste management hierarchy rules, where the first steps are to reduce the waste and then to reuse and recycle the remaining waste. Certain fractions can be recovered (recycled or composted), such as: paper, glass, metals, plastics or bio-waste. They should be collected separately so that the recycling process is easier.

The treatment of biowaste can be done by several means, such as: anaerobic digestion (AD) (most favourable), composting, incineration, and landfill (least favourable). Their hierarchy is shown in the figure 3. The largest advantage of AD is that it recycles nutrients and generates energy. Disposal is the last option and should be avoided. Nevertheless, it should be mentioned that not all types of various biodegradable waste is suitable for AD, as shown in the table 1.

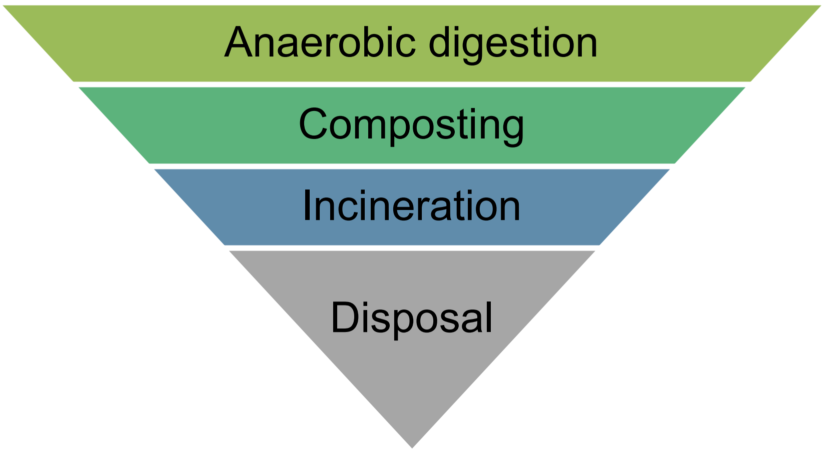

Figure 3. Possible treatments of biowaste

According to the report on biowaste management in EU[4], produced biowaste is between 118 and 138 million tonnes every year, of which about 88 million tonnes is municipal waste.

Even though the benefits of AD or composting of biowaste is more than evident, still 40% of this waste is landfilled. The use of municipal biowaste for energy utilization has two main advantages: protection of the environment by avoiding the waste deposit and the production of energy from the renewable energy sources.

The improvement of biowaste management (figure 4.) will contribute to a better use of resources and can open-up new markets and jobs, as well as encourage less dependency on imports of raw materials and lower impacts on the environment. In that sense, the EC has often proposed very large fines for those who are not adhering to the rules. It has been an obligation to all EU members to transpose the Waste Framework Directive[5] into national law.

Table 1. Suitability of different biowaste treatments

Type of waste	Combustion	Composting	Anaerobic Digestion
Liquid manure	no	partially	yes
Sewage sludge	partially	partially	yes
Biowaste	partially	yes	yes
Grass from lawns	no	yes	yes
Sewage from industry	no	partially	yes
Waste grease	partially	no	yes
Wood	yes	yes	no
Excrement	no	yes	yes
Straw	partially	yes	partially

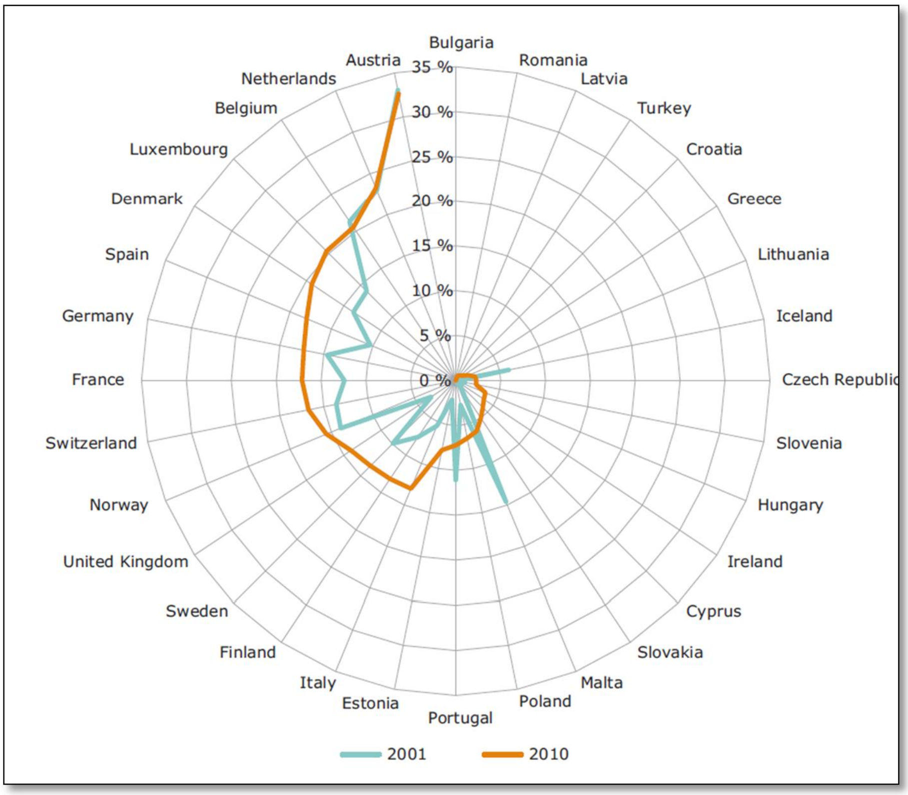

Figure 4. Bio-waste recycling as a percentage of municipal waste generation in 32 European countries, 2001 and 2010[6]

4 FOOD WASTE TYPES

Currently, the main environmental concern about food waste is its reduction and its deviation from landfilling to more suitable conversion, such as AD. The waste management hierarchy generally lays down a priority order of best environmental options in waste legislation and policies. Even though strong effort has been made in this direction, food waste is still being produced along the whole food supply chain: from the farm, to the processing and manufacturing, sales in shops, and consumption in restaurants, canteens and households. The main groups of food waste producers are shown in figure 5.

Figure 5. Different food waste producers

Most common waste producers of food waste in urban areas are: households, restaurants and canteens (kitchen waste), market places and retail stores (expired food waste), and also waste from food and beverage industry.

Considering all waste producers, the hardest challenge for municipalities or the waste management companies is the introduction of separate waste collection from households, which consists large amount of food waste. The presence of contaminants in this waste requires a sophisticated process to receive a high-quality digestate at the end of the process. Therefore, it is important to increase the public acceptance about the separate waste collection and to control the process. If random samples show high level of contaminations, the introduction of fines should be considered. Also, a frequent argument for poor separate collection is the lack of financing. However, there are many good examples on separate biowaste collection from households in the EU (some of them are presented in the report D2.1 of this project). A step forward in overcoming these issues could be the mandatory introduction of separate biowaste collection for all EU members. Currently the waste legislation is only encouraging the MS to introduce separate biowaste collection.

The production of food waste from the food processing steps is often unavoidable during the transformation of raw materials to market products. The quality of such waste fractions is often satisfactory so that this material can be easily used for energy generation and digestate production.

However, sometimes these wastes are mixed with other waste fraction (e.g. packaged products) so they have to be sent to deconditioning units before being treated.
Food waste is usually from following industry sectors:

- Meat and fish industry,
- Fruit and vegetable industry,
- Dairy industry,
- Baking industry,
- Milling industry,
- Sugar industry,
- Distilleries and wine production,
- Breweries and malt production;

The European list of waste[7] is official document where all types of waste fraction are named and described. It has been introduced to have a proper waste classification, and it is a harmonized list of waste from its origins. The different types of wastes in the list are fully defined by six-digit codes for the waste and by the respective two-digit and four-digit chapter headings. This implies that the waste producers can identify their wastes in the list. Examples of the different waste streams which are suitable for biogas production are shown in table 2.

Table 2. Biowaste suitable for AD treatment

02	**Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing**
02 02	Wastes from the preparation and processing of meat, fish and other foods of animal origin
02 03	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation
02 04	Wastes from sugar processing
02 05	Wastes from the dairy products industry
02 06	Wastes from the baking and confectionery industry
02 07	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa)
20	**Municipal wastes and similar commercial, industrial and institutional wastes including separately collected fractions**
20 01	Separately collected fractions
20 01 08	Organic kitchen waste
20 01 25	Edible oil and fat
20 02	Garden and park wastes (including cemetery waste)
20 02 01	Biodegradable waste

ANIMAL BY-PRODUCTS

Animal by-products (ABP) are not intended for the human consumption as they are a potential source of risks to public and animal health. They are produced during the slaughtering of animals for human consumption, during the processing of products of animal origin such as dairy products, and in the course of the disposal of dead animals and during disease control measures.
Regardless of their source, they pose a potential risk to public and animal health, as well as to the environment. This risk needs to be adequately controlled, either by directing such products towards safe means of disposal or by using them for different purposes, provided that strict conditions are applied which minimise the health risks involved.
The ABP[8] regulation is covering all aspects related to the collection, treatment, storage and use of ABP, and they are classified into three categories which reflect the degree of risk to the human or animal health. Categories of ABP are shown in the table 3.

Table 3. Categorisation of animal by-products

Category	Description
CAT 1	• Very high risk • Bodies of diseased animals, bodies of pets, and specific wastes from kitchen and the food industry. • Products are not allowed to be processed in biogas plants.
CAT 2	• High risk • Bodies of the livestock husbandry, unusable slaughterhouse disposals, liquid manure, gastrointestinal contents, milk. • Products are allowed to be processed with specific permission and after a certain preparation process (pressure sterilization).
CAT 3	• Low risk • Slaughterhouse disposals of animals, wastes from kitchen and food industry. • Products are allowed to be processed in biogas plants after pasteurization (hygienization).

In case ABP`s will be used for biogas production, it must be assured that hygienic requirements are fulfilled. They have to be stored properly in special containers undergo dedicated procedures regarding the preventive measures (such as cleaning, hygiene control, digestate handling, etc.). Anaerobic process of ABP must be well established with good agitation, balanced feedstock mixture and stable temperature level, in order to prevent growth of pathogens organisms. Usually a sanitation step where the material is e.g. heated up at 70°C for at least one hour, is included.

5 ENERGY POTENTIAL

During the process of anaerobic digestion, organic material is broken down in several steps by different types of microorganisms. As a result of this process biogas is produced which mainly consist methane and carbon dioxide. The remaining fraction of the process is the digestion residue or digestate. Since input materials usually consist of different organic fractions, as municipal waste is usually a heterogeneous substrate, the energy potential in the AD process is depending very much on the waste characteristics.
Biogas can be produced from various types of organic material, some materials are more or less suitable, except for lignin which cannot be degraded by anaerobic digestion. The composition of the produced biogas depends on different parameters: input materials, process technology, etc. The typical composition of biogas is presented in the table 4.

Table 4. Composition of biogas

Compound	
Methane (vol %)	60 – 70
Hydrogen (vol %)	0.1
Carbon dioxide (vol %)	30 – 40
Nitrogen (vol %)	0.2
Oxygen (vol %)	0.1
Hydrogen sulphide (ppm)	0 – 4,000
Ammonia (ppm)	100

The biodegradability and biogas potential of the various waste substrates depend on the content of carbohydrates, lipids and proteins, as well as on the composition of cellulose, hemicellulose and lignin fractions. Due to the different percentage of these fractions in collected food waste its biodegradability differs, as well as its methane content as most important compound in biogas. As previously mentioned, one of the important parameters for sufficient treatment of municipal organic material is efficient waste collection system. Source segregated collection provides higher quality of biowaste, together with lower contamination level (e.g. plastics, inert materials). This is especially important when food waste is being collected from households, due to the reasons elaborated in previous chapters. The produced biogas can be utilized for combined heat and power (CHP) production, or upgraded to biomethane and fed directly into the gas grid as natural gas substitute.

The main objective of the Bin2Grid project is to promote the use of produced biomethane as a biofuel. Thus, the methanogenic potential of different waste streams is important information for further development of FoodWaste-to-Biofuel concepts in the Bin2Grid target cities and beyond. A list of different waste fractions (substrates) produced in various sectors is shown in the table 5.The dry matter is one of the most important parameters that define the mass of matter when it is completely dried. It helps biogas plant operators to decide how to storage and treat waste, whether it is solid or liquid fraction. Produced methane is a colourless and odourless gas and the main energy source in biogas with a density of 0.71 g/L (25 °C, 1 atm). Also, in the table is presented mileage for the waste collection truck based on average biogas yield and the average gas consumption of 20m^3 of CH_4 per 100km (consumption in ZCH fleet). Consumption of collection truck is depending on many parameters: number of collection stops, location of the collection route, etc.

Table 5. List of different substrates for AD with energy potential[9, 10]

Substrates	Dry matter (%)	Biogas yield (m^3/t, FM)	Methane content, (%)	Mileage (km/t of waste)
Waste from the food industry				
Mash from fruits	3 - 5	250 - 540	63	1,260
Mash from distillations	3 - 8	400 - 450	62	1,320
Cereal mash	5 - 8	80 - 100	63	285
Potato mash, potato pulp	5 - 16	250 - 800	55	1,238
Potato pulp dried	85	500 - 600	55	1,520
Oilseed residuals, pressed	90	420 - 720	66	1,980
Wheat flour	86	540	58	1,570
Malt germ	90	580	55	1,600
Baking waste	60 - 80	400 - 500	62	1,395
Whey	4 - 6	50 - 140	58	290
Skimmed milk, dry	75	400 - 520	60	1,380
Cheese	30	320	58	930
Waste from beverage industry				
Grains	20 - 25	180 - 300	60	780
Grains, dry	90	550	62	1,705
Apples	22 - 40	420 - 510	68	1,565
Apple mash	2 - 5	420	60	1,280
Fruits, mixed	25 - 45	400 - 650	68	1,905
Vinasse from alcohol prod.	8 - 12	50	55	140
Vegetables, greens, grass				
Mixed vegetable waste	5 - 20	300 - 400	62	1,085
Leaves	75 - 90	10 - 20	56	42
Greens (fresh)	80	40 - 80	58	175
Grass silage	22 - 36	320 - 420	55	990
Maize silage	20 - 40	160 - 200	55	495
Rice straw	25 - 50	320 - 450	50	1,000
Market wastes	8 - 20	250 - 450	60	960
Wastes from households and canteens				
Mixed biowaste	35 - 75	100 - 220	62	495
Grass, green waste	25	180	56	505
Food leftovers (kitchen)	9 - 37	180 - 360	58	755
Overstored food leftovers	14 - 18	210 - 540	55	1,045
Dry bread	65 - 90	620 - 880	58	2,030
Mixed fat	80 - 95	1,100	66	3,630
Eggs	25	380 - 520	54	1,245
Low-fat milk	8	560	55	1,540
Frying oil and fat	50 - 70	600 – 750	62	2,100
Animal by-products				
Slaughterhouse waste	-	320 - 600	55	1,320
Meat and bone meal	8 - 25	750 – 1,100	55	2,475
Animal fat	-	1,000	65	3,250
Blood liquid	18	420	60	1,280
Guts (pigs)	-	60	55	165

6 CONCLUSION

Different EU legislations address the issue of sustainable biowaste management since it is a priority to have high human and environmental protection standards during the whole waste management process. Anaerobic digestion in closed systems with proper control measures will generate high yields of biogas.

Separate collection will divert biodegradable waste from landfill and have positive impact on overall employment. This is a step towards more sustainable waste management as it allows waste recovery and recycling, as well as the preservation of the natural resources.

Anaerobic digestion has become a standard technology for the treatment of separately collected digestible organic fraction of municipal waste in many countries, producing biogas/biomethane which can be used as a renewable biofuel, as well as digestate which can be used as a plant fertilizer.

The quality of the source separated waste material is vitally important, as it is the guarantee that recycling of digestate as fertiliser is safe for the environment and for human and animal health, ensuring viable markets applications in agriculture, horticulture and forestry.

This report has shown the energy potentials in different fractions of organic waste and from various waste producers (households, retail and catering, food and beverage industry).

In that sense, source separation of digestible household waste and other streams is a sustainable practice, and should become standard for future municipal waste management. The economics of source separation of digestible household waste are highly dependent on existing waste management policies and the socio-economic frameworks offered by such policies.

There are good reasons for municipalities to introduce source separation of digestible waste streams and to create premises for their use as feedstock for AD. Source separation of wastes is essential to meet the necessary standards of quality required by waste recycling. The benefits for the environment, as well as for human and animal health are widely recognised, and the estimation of the costs-involved has shown not to be disproportionate to the benefits.

7 REFERENCES

[1] Roadmap to a Resource Efficient Europe;

[2] Directive 199/31/EC on the landfill of waste;

[3] European Commission (2015): http://ec.europa.eu/environment/waste/compost/

[4] Communication on Future Steps in Bio-Waste Management in the European Union, COM (2010)235;

[5] Directive 2008/98/EC on waste (Waste Framework Directive);

[6] EEA, Managing municipal solid waste, 2013;

[7] Commission Decision on the European List of Waste, COM 2000/532/EC;

[8] Regulation on animal by-products not intended for human consumption, 1774/2002;

[9] Deublein, Steinhauser, Biogas from waste and renewable resources, 2008;

[10] Voća, N.; Jurišić, V.; Pavković, B.; Dragičević, V.; Delač, B.; Šegon, V.; Maras, H.; Jardas, D.; Čotar, A.; Ribić, B. Feasibility study of biogas production at the island of Krk, Croatia, Zagreb, 2012;

[11] Ribić, Galović, No time to waste, Cohesion Funds programming for a resource-efficient Europe, 2013;

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