# D4.1 | Report on data availability of selected raw material categories

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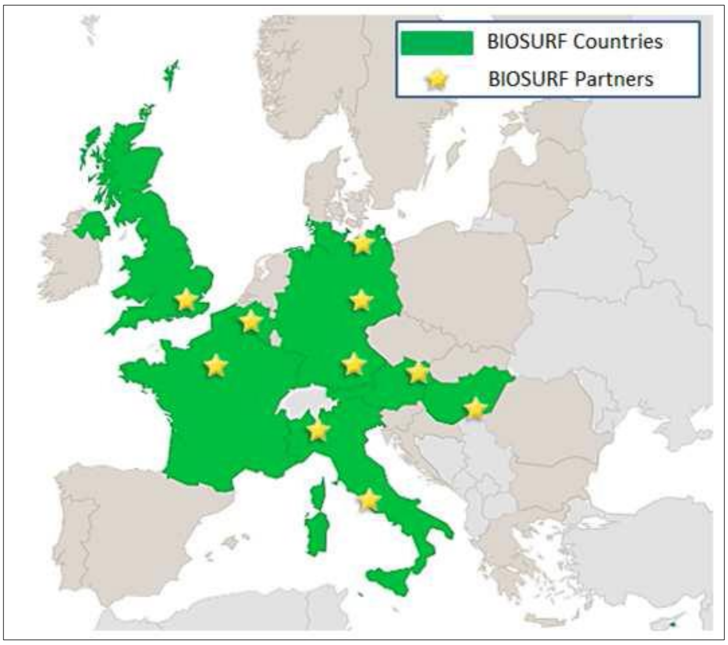
## BIOSURF IN A NUTSHELL

BIOSURF (**BIO**methane as **SU**stainable and **R**enewable **F**uel) is an EU-funded project under the Horizon 2020 programme for research, technological development and demonstration.

The objective of BIOSURF is to increase the production and use of biomethane (from animal waste, other waste materials and sustainable biomass), for grid injection and as transport fuel, by removing non-technical barriers and by paving the way towards a European biomethane market.

The BIOSURF consortium consists of 11 partners from 7 countries (Austria, Belgium, France, Germany, Hungary, Italy and United Kingdom), covering a large geographical area, as indicated in the figure on the left.




The intention of the project is:

- To analyse the value chain from production to use, based on territorial, physical and economic features (specified for different areas, i.e., biofuel for transport, electricity generation, heating & cooling);
- To analyse, compare and promote biomethane registering, labelling, certification and trade practices in Europe, in order to favour cooperation among the different countries and cross border markets on the basis of the partner countries involved;
- To address traceability, environmental criteria and quality standards to reduce GHG emissions and indirect land-use change (ILUC), as well as to preserve biodiversity and to assess the energy and CO2 balance;
- To identify the most prominent drivers for CO2-emissions along the value chain as an input for future optimization approaches and to exchange information and best practices all across Europe with regard to biomethane policy, regulations, support schemes and technical standards.

## SUMMARY

The production of renewable energies in the EU and is expected to further increase. The use of agricultural residues and other waste materials is strongly promoted in this context. Used as feedstocks for bioenergy purposes they are considered as sustainable alternative compared to other feedstocks like for instance energy crops, which also could be used in the food and feed sector. Since sustainable biomass is a limited resource, meta-analyses of respective potentials are crucial to pursue the right direction in the further development of the sustainable bioenergy sector. Three main biomass categories were of particular interest in the development of this survey report: animal waste (slurry and manure), other waste materials (municipal bio-waste and food/ feed residues) and biomass residues like agricultural crop residues, by-products from cultivation, harvesting and processing, residues from landscape maintenance and conservation, including pruning material and catch crops. The report gives an overview of different national and international studies on that topic aiming to show the quality and quantity of data availability regarding the potential of waste and residue biomass in different countries.

Most identified studies in this survey have been conducted on EU-Member States level and mostly include the countries represented by the participants in the BIOSURF project (Italy, Austria, Germany, France, Hungary, and UK). These studies, partly in form of "roadmaps", often make projections for different scenarios in the future, e.g. 2020. Regarding national studies, the results of the survey were quite diverse (focus was on the countries represented in BIOSURF): data on availability, use and potential of biogenic residue and waste materials are scarce for Hungary, France and Italy, more frequent for Austria and the United Kingdom and best covered in Germany.

Even though the report does not claim to give an exhaustive overview on this topic, it nevertheless includes the most current and best known studies and data portal links and will provide a good impression on the coverage of this topic in different European countries, showing existing gaps. In order to reduce them, further assessments and data collections should be encouraged - possibly in the framework of future projects.

# 1. INTRODUCTION

The expected increase in total biogas and biomethane production respectively and its targeted trade across borders (via the national gas grids) raise the concern of safeguarding the sustainable raw material supply. In this context, the establishment of a harmonized approach for national biomethane registries is being pursued, which would, among others, increase traceability and transparency of the feedstock use. Furthermore, the project actually assesses the availability and potential of previously defined sustainable feedstock sources. In this context, sustainability criteria and indicators will be discussed and a guideline on sustainable raw material supply will be developed. In a first step, the respective data availability on sustainable feedstock sources in different European countries is being assessed, evaluated and inventoried.

This report will describe the selected sustainable feedstock categories with respect to data availability and their potentials in different European countries. This literature review will serve as basis for the consecutive evaluation and comparison of data and will already provide an outlook on the validity of describing respective feedstock potentials for biomethane production in the considered countries.

# 2. Selected Raw Material Categories for Biomethane Production and Respective Data Availability

The use of agricultural residues and other waste materials is strongly promoted in order to contribute to the achievement of renewable energy targets, to mitigate climate change and to reduce competition for resources and land. Used as feedstocks for bioenergy purposes, they are therefore considered as sustainable alternative compared to other feedstocks like for instance energy crops, which also could be used in the food and feed sector. In consequence, the following assessment of data about sustainable feedstocks for biomethane production will focus exactly on these feedstock categories. Each of these biomass categories comprises different types of biomass.
Three main categories will be of particular interest in this respect: animal waste (slurry and manure), other waste materials (municipal bio-waste and food/ feed residues) and biomass residues like agricultural crop residues, by-products from cultivation, harvesting and processing, residues from landscape maintenance and conservation, including pruning material and catch crops.

Potential biomass feedstocks for the production of biomethane are subject to competitive use.

The studies listed (**Errore. L'origine riferimento non è stata trovata.** in Chapter 3) consider theoretical and/or technical biomass potentials. However, a specific amount of the feedstock categories is already being used and is not available for the market. The biomass categories examined here, are not in competition with food production but partially with the sectors 'feed, fuel and fiber'. The available amount of feedstock is of economic interest and the available feedstock potential should be considered in future studies. Account should be taken on the identification of the current use and range, the identification of the best utilization pathways (economic and ecologic) for the limited feedstocks and the optimization of existing utilization pathways by cascade systems.

## 2.1 Animal Waste (Slurry and Manure)

### 2.1.1 Definition

Animal husbandry results in the by-production of animal waste, also called agricultural primary residues. The waste can be used as raw material for biogas and subsequently biomethane production. However, only animal waste produced from indoor housing can be obtained for energetic purposes. The main part of animal waste from sheep, goats, horses, gooses and ducks is not usable for energy applications due to the high proportion of free range systems of these animals (BMVBS 2010). Therefore most studies about the energy potential do not include animal waste from these types of animals. Great quantities of animal waste from indoor housing, originate in the European Union from cattle and pig farming and minor amounts from chicken farming. Manure from chickens is used in biogas plants in limited amounts because of high ammonia contents and high proportions of lime due to supplementary feeding (FNR 2010).
Animal waste can be subdivided in two main groups: liquid and solid waste. "Slurry" is animal waste in liquid form, consisting of more or less solid excrements and urine of domestic animals, including possibly also water and/or small amounts of litter. "Manure" is a mixture of excrements of domestic animals which includes materials of animal bedding such as straw or chips. The nature (solid or liquid) of animal excrements depends partially on the food quality (fresh/liquid fodder, dried fodder). The yields for biogas and methane differ between slurry and manure and between animal species but also depend on the age of the animal waste (outgassing).
Due to the water content, the biogas and methane yields per volume of fresh substrate are higher for manure in comparison to slurry (FNR 2010). However, the storage in slurry tanks, the co-digestion

with other substrates and the application of slurry in biogas plants is easier due to the flow behavior (pumpability) in comparison to manure, which needs special filling techniques.
With increasing proportion of indoor systems and farm sizes, the technical/economic potential is increasing, since a minimum quantity of animal waste has to be produced on a farm or location to ensure the profitability of a biogas-plant and the profitability of the biomethane-production.
Animal waste can be used for the commercial energy production on and near farms without competing with the supply needed for fertilization. The material is easy to ferment and can be applied as fertilizer on the fields. Significant advantages of the fermentation residues compared to untreated animal waste are the reduced odor emissions, the homogenization of the substrate which makes it more readily spreadable, the shifted ratio of phosphorus to potassium and increased proportion of inorganic nitrogen which satisfies better the nutritional needs of plants and the fewer pathogens and weed seeds (Insam, Gómez-Brandón, and Ascher 2015).
However, the economics might not be beneficial to all farmers, since the methane yield per mass unit of animal waste is comparatively low. Therefore, co-digestion with other substrates (e.g. energy crops, crop residues) is common and their availability near the biogas plant should be included in (future) evaluations. Under the aspects of climate protection, the energetic utilization of animal waste is essential for the reduction of GHG-Emissions. The emission of greenhouse gasses are reduced in several ways: the production of renewable energy substitute fossil fuels, methane emissions from anaerobic digested animal waste are lower than from storage tanks due to the lack of easily degradable organic compounds (Sommer, Moller, and Pedersen 2001)(Meyer-Aurich et al. 2012) and emissions of nitrous oxide after application of digested animal waste to the field is reduced in comparison to undigested material (Sommer, Moller, and Pedersen 2001). The leak of methane and ammonia from biogas plants can be eliminated by technical solutions.
A further ecological advantage of digestate is the option to concentrate the material by e.g. pressing. The concentrate can serve as a green fertilizer with increased economic transportability and could provide largely agricultural land with nutrients while reducing the nitrate impact in areas with intensive livestock farming.
Digestate is used for closing the nutrient cycles, for the production of renewable energy and offer the option to reduce nitrate impacts in areas with intense livestock farming. Competition for food and feed production is not given.

### 2.1.2 Literature Review

*Biomass potential*

Most studies about animal waste potential are conducted for the EU-Member States and make projections for different scenarios in the future, e.g. 2020, 2030 ((Elbersen, Startisky, Hengeveld, Schellhaas, and Neaff 2012); (European Environment Agency 2006); (Pudelko, Borzecka-Walker, and Faber 2013)). National studies are scarce for Hungary (Szunyog 2008); Austria (Kalt, Matzenberger, and Kranzl 2011); (Kranzl et al. 2008; Proidl et al. 2012), France (ADEME 2013) and United Kingdom (DEFRA 2011; Howes et al. 2011; Rosillo-Calle and Galligani 2011; Slade, Bauen, and Gross 2010) and more frequent for Italy (Colonna, Alfano, and Gaeta 2009; MIPAAF 2008; Motola et al. 2009) and Germany (Brosowski et al. 2015; Kaltschmitt et al. 2003; Majer et al. 2013; Öko-Institut et al. 2004; Universität Rostock, Institut für Energetik und Umwelt gGmbH, and Bundesanstalt für Landwirtschaft 2007) and are mostly based on data older than 5 years.
Studies about animal waste potential are mostly part of extensive meta studies about biomass potentials (Elbersen, Startisky, Hengeveld, Schellhaas, and Neaff 2012; Pudelko, Borzecka-Walker, and Faber 2013; BMVBS 2010). The considered categories are heterogeneous. Main categories, which include animal excrements, are e.g. waste (including different sub-categories, depending on the study); animal waste (including slaughterhouse waste); waste from agriculture (including primary and secondary residues) or the category animal waste + grassland.

The category animal waste (excrements) includes partially waste from bovine animals, cattle, pigs and/or poultry and is partially differentiated in different types of solid and liquid excrements, depending on the study.
The transparency of calculations in the reports is not always sufficient to track the applied method. Methods for the calculation of animal waste were reviewed in (Vis et al. 2010) and a calculation model was developed. All calculations of animal waste are based on animal numbers and the specific quantities of excrements per head or livestock unit for the respective livestock category. Base data of animal numbers are raised by the national agricultural statistic authorities every two years. These statistical evaluations are obligate for all EU-Member States. The data are compiled and made available by EuroStat up to NUTS2-Level (Http://ec.europa.eu/eurostat/de/data/database n.d.). Data with higher resolution are available at national statistic authorities. Data about animal waste production per livestock unit are listed in e.g. (KTBL 2009) and FAO-Stat (http://faostat3.fao.org/browse/Q/*/E n.d.). The Phyllis-database (https://www.ecn.nl/phyllis2/ n.d.) provides information about the composition of biomass and waste, e.g. ash content and calorific values for different types of animal waste.
Animal waste from free-range farming cannot be rescued for technical applications. Therefore in some studies (Elbersen, Startisky, Hengeveld, Schellhaas, and Neaff 2012; BMVBS 2010; Foged et al. 2012; Thrän et al. 2004) the availability of animal waste was calculated with the ratio of the animal housing number of days per year (database: (Http://ec.europa.eu/eurostat/statistics-explained/index.php/Farm_structure_statistics n.d.)). Some studies consider the losses during storage (Pudelko, Borzecka-Walker, and Faber 2013) and the minimum amount of animal manure per farm for the economic operation of the plant (Brosowski et al. 2015) or taking the Nitrate Directive into account and calculate the biomass potential for biogas plants if the production of nitrogen associated with the amount of livestock manure exceed an specific value of nitrogen per hectare (maximum dose limit nitrogen = 170 kg n/ha) and thus, increase the interest of farmers in alternative use of residues (Pudelko, Borzecka-Walker, and Faber 2013).
Results are published in reports (see **Errore. L'origine riferimento non è stata trovata.**, Chapter 3) or are given as geodata in geoportals, such as the Atlante Nazionale Biomasse for Italy (http://www.atlantebiomasse.enea.it/ n.d.); (MIPAAF 2008) established by ENEA (Agenzia nzionale per le nuovo tecnologie, l'energia e lo sviluppo economico sostenibile) and the geoportal for the EU-Member States created in the BioBoost-Project (Http://iung.neogis.pl/geoportal/ n.d.); report: (Pudelko, Borzecka-Walker, and Faber 2013).

*National and international Projects; Associations*
Analyses about biomass potentials in a European context ensure comparable data across countries due to harmonized methods within the respective studies.
International studies were commissioned by administrative departments, such as:

- BMVBS (Bundesministerium für Verkehr, Bau und Stadtentwicklung) - commissioned an analysis of global and regional biomass potentials (BMVBS 2010), the analysis of animal waste was conducted by DBFZ (Deutsches Biomasseforschungszentrum).
- EEA (European Environment Agency) – commissioned two studies about the bioenergy potential in EU-Member states (European Environment Agency 2006);(ETC/SIA 2013)
- European Commission, Directorate - General Environment – commissioned a study about manure processing and manure potentials in EU-Member states (Foged et al. 2012)

The most relevant international projects focusing on biomass (including animal waste) potentials are:

- BEE - http://www.eu-bee.eu/ is an international project which focusses on biomass assessment and harmonization of methods (Nils Rettenmaier, Schorb, and Köppen 2010).

- CEUBIOM – is an ongoing twin project of BEE which focusses on biomass assessments and the integration of multiple data sources. Final reports and results are not available at present.
- BIOMASS Futures - http://www.biomassfutures.eu compiled a review of biomass assessment, and an atlas of technical and economic biomass potential (Elbersen, Startisky, Hengeveld, Schellhaas, Naeff, et al. 2012).
- BioBoost - http://www.bioboost.eu/home.php analyses feedstock, their potentials, supply and logistics (Pudelko, Borzecka-Walker, and Faber 2013) and created a geoportal for feedstock potentials (Http://iung.neogis.pl/geoportal/ n.d.).
- S2Biom - http://www.s2biom.eu/en/ focusses on the delivery of sustainable supply of non-food biomass feedstock at local, regional and pan-European level. A review paper on the state of the art refers to the analysis of (Elbersen, Startisky, Hengeveld, Schellhaas, and Neaff 2012) from the BIOMASS Project.

Relevant associations which provide data about renewable energies and (partially) feedstock are:

- EBA (European Biogas Association) - http://european-biogas.eu/ provides annual reports;
- IEA (International Energy Agency) – managing Task 37 and Task 40. Task 37 is an international working group which covers the anaerobic digestion of biomass feedstocks including agricultural residues (e.g. manure and crop residues). The country reports give information about the number of biogas plants in operation and biogas production data (IEA 2015). Task 40 identifies domestic biomass resources in each member states as well as their current use, trends, and main users.

## 2.2 **Other Waste Materials** (Municipal Bio-Waste; Food and Feed Residues)

### 2.2.1 Definition

Other organic waste materials considered in this paper are defined under the waste frame work directive (2008/98/EC) in article 3 point 4 as: 'bio-waste' means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants.

There are usually several classifications under this definition made. The regulation on waste statistics (EC 2150/2002 amended through EC 849/2010) defines, under section 2, two categories for bio-waste: animal and mixed food waste and vegetal wastes. These categories differ sometimes between countries and scientific reports for different reasons including national laws, bio-waste collection strategies, statistical requirements, etc.

Although efforts have been made to reduce the amount of bio-waste from households in some member states (e.g. Germany, Austria), during the last years there is still a considerable amount of bio-waste derived from food, feed and beverage production and consumption that cannot be avoided. One of the best options for dealing with this organic waste stream is its treatment and use in a biogas plant producing energy and an organic fertilizer.

It has to be considered that several bio-waste streams, mainly from beverage and food processing, are still not on the market as waste streams but as fodder like spent grains, whey etc. Therefore, in the available data, these bio-waste streams are not included. In respect of the further development of a sustainable circular economy, the cascade use of feedstock should be encouraged and the use of bio-waste feedstock in biogas plants should be the last step. Nevertheless, due to the increasing size of food and beverage production sites and with upcoming logistic problems, an increasing number of biogas plants, which are directly situated at those sites using the incurring bio-waste, can be expected to the already existing plants treating those bio-waste streams.

Although some member states already introduced separate collection of biodegradable waste and some member states additionally set out a ban on landfilling of biodegradable waste (AT, BE-FL, DE, DK, SE), there are still huge amounts in EU which are landfilled. Through the fully implementation of the landfill directive (1999/31/EC), which forces to lower the amount of biodegradable waste in landfills, in all member states, we can expect a big increase of separate collected bio-waste within next years.

The majority of the separate collected bio-waste from households is currently still treated in compost plants. Due to further regulations and developments in the biogas sector, an increasing amount of bio-waste material from this category can be expected for digestion.

### 2.2.2 Literature Review

There are many scientific reports about the amount of organic waste within collected municipal waste available at regional level. As the definition of collectable municipal bio-waste is not always consistent in the reviewed studies, a comprehensive assessment of existing data is very difficult. Additionally bio-waste from food, feed and beverage production, which is currently used as fodder is not statistically recorded. Only FAB biogas provides estimations on this topic.

A good categorization and description of organic waste in EU gives the IEA brochure: Source separation of MSW (Al Seadi et al. 2013).

DBFZ (Deutsches Biomasseforschungszentrum) published a study about biomass potential including bio-waste called “Global and Regional Spatial Distribution of Biomass Potentials” (BMVBS 2010).

University of Rostock published a study about dry digestion techniques that also includes biomass potential from organic waste: “Biogaserzeugung durch Trockenvergärung von organischen Rückständen, Nebenprodukten und Abfällen aus der Landwirtschaft” (Universität Rostock, Institut für Energetik und Umwelt gGmbH, and Bundesanstalt für Landwirtschaft 2007)

BMELV (federal ministry for food and agriculture of Germany) ordered a study about discarded food called: “Ermittlung der Mengen weggeworfener Lebensmittel und Hauptursachen für die Entstehung von Lebensmittelabfällen in Deutschland” (Universität Stuttgart 2012).

UBA (federal environment agency of Austria) published a bio-waste strategy: “Bioabfallstrategie” (Lampert, Reisinger, and Zethner 2014)

## 2.3 Residues (Agricultural crop residues and by-Products, residues from landscape maintenance and conservation, pruning material, catch crops)

### 2.3.1 Definition

The term “residue” comprises very different types of biomass. All of them have in common that they are by products of utilization pathways that were originally not intended to produce bioenergy. Besides municipal and agro-industrial bio-wastes and animal excrements, biomass types that were already described earlier, this biomass category also includes crop residues (mainly straw), and residues from landscape maintenance and conservation, incl. pruning material and catch crops.

**Crop residues** are parts of the crop that are not harvested during standard agricultural operations. Significant amounts of agricultural residues are generated from agricultural crop production and partially remain in the field after harvest. Residue production depends on a number of factors that include the types of crops, crop rotation, crop mix and agricultural practices. A large annual variation in crop production and consequently in the remaining residues has to be taken into account when making assumption about the respective potential for bioenergy use. In the EU there are considerable differences in terms of cultivated area, types of crops and yields due to climate and soil conditions, accessibility and farm practices. Cereals and oilseeds are the most cultivated crops (Scarlat, Martinov, and Dallemand 2010). The availability of residues further depends on the amount that can be removed from land without neglecting land fertility and on their competitive use for other agricultural or industrial purposes.

The estimation of agricultural crop residues for bioenergy production requires accurate data on their availability by crop type. Data on crop yields are directly available, while data on their residues are not, since the sole focus of agricultural production has obviously been on the main food/feed product in the past. In the meantime, there are many studies which estimated crop residue availability in the EU.

Straw from cereal, maize and rapeseed production is the main crop residue (figure 1), which is already used for many different purposes. The majority of the available (cereal based) straw is used for animal housing or remains on the field to guarantee lasting soil fertility. Sometimes it is simply left on the field because the straw is not further needed and suitable, economically interesting concepts are missing. Only about 20 % of the straw can be used for energy (Agentur für Erneuerbare Energien (AEE) 2013): straw is used in heat and power plants as well as in biogas plants and its use for bioethanol production is currently introduced on the market. A study by the Bloomberg New Energy Finance (Bloomberg New Energy Finance 2012) assumed in their estimation that 82.5% of residues are required for soil quality, which reduces the potential of straw for bioenergy uses significantly.

**Figure 2-1** summarizes and visualizes the average share of crop residues in Europe.

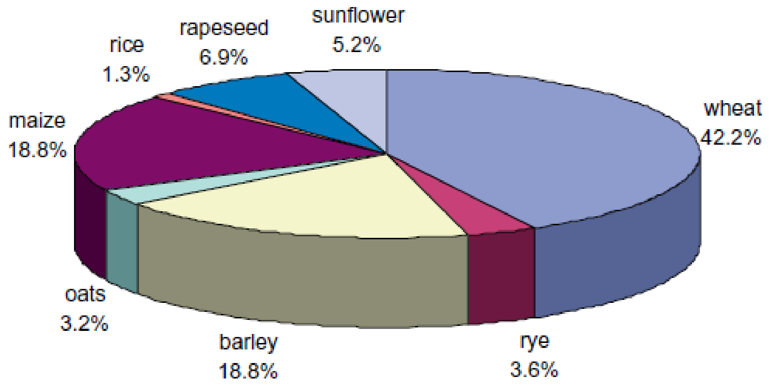



***Figure 2-1:*** *Share of 8 crop residues produced in EU-27 (Scarlat, Martinov, and Dallemand 2010)*

**Landscape Maintenance Material and Pruning Residues**

There are many other primary residues that can supply biomass for bioenergy such as cuttings of permanent grasslands which are sometimes found on agricultural lands (in this case usually used for hay or silage production and its further use in animal husbandry), but which also originate from parks or other recreational areas, nature conservation areas or dykes and abandoned grasslands. Management of abandoned areas through cutting can be beneficial for biodiversity. In a certain amount, human intervention stimulates larger diversity since it prevents one floristic species to become dominant over others. In consequence more ecological niches are created for a wider range of species (Khawaja and Janssen 2014). The incurring biomass coming from the named grasslands can then potentially be used as feedstock for bioenergy production.

Woody material from pruning and cutting, which is also part of landscape maintenance, can deliver a large potential of biomass. In certain regions of the EU, plantations of soft fruit, citrus, olives and vineyards cover quite a significant area (Khawaja and Janssen 2014). With respect to potential applications for bioenergy production, these residues however face constraints due to their relatively high cellulosic content and in some cases also the presence of natural biochemical substances, which make the material badly degradable and hamper the digesting process. A pre-treatment is necessary in these cases. Consequently, woody material derived from landscape maintenance can only be used in small amounts for the treatment in biogas plants. Most of the material is therefore currently used to produce woodchips for heating instead or is directly used for thermal processes. There are several processes to treat this kind of biomass physically, chemically or biologically and to convert the material into other primary energy carrier to make the subsequent energetic conversion more efficient. Producing energy through anaerobic digestion is just one of these option (Universität Rostock, Institut für Energetik und Umwelt gGmbH, and Bundesanstalt für Landwirtschaft 2007). However, at present thermochemical technologies seem to be the most efficient conversion technology for material with a high fibre content compared to biochemical processing. The potential for the use of woody material as biogas feedstock could nevertheless increase when suitable pre-treatment measures are further developed and can be implemented on an economical viable level.

**Roadside verge grass** can be another source of biomass supply. The Biomass Futures project provided some estimations on the potential amount of this kind of biomass (Elbersen, Startisky, Hengeveld, Schellhaas, Naeff, et al. 2012).The German/ Dutch project “Biores” also found a considerable potential of this kind of (residue) biomass. Particularly in countries with limited arable farming like the Netherlands, roadside verge grass presents a quite interesting alternative to the cultivation of catch crops and their use for the biogas process (Helmer and Böller 2010).

**Catch crops** represent another alternative for using “residues” for biogas/ biomethane production. Catch crops are sometimes cultivated together with the main crops, but are mostly used to bridge the time in between main crop cultivation, when the area would otherwise just consist of delicate fallow land. In this context catch crops help to prevent water and wind erosion, nutrient leakage and consequently soil deterioration. The use of catch crops in biogas plants is being tested in several research projects. The German/ Dutch project “Biores”(Helmer and Böller 2010), for instance, found that the use of summer rape (seeded until June) and winter cereal is good and economically interesting catch crops for biogas producers. A study conducted by a research team of the University of Soil Science in Vienna (BOKU) further revealed that a mixture of maize, sorghum/ millet and sunflower or sudan-grass and sorghum by itself are achieving promising biomethane yields (Amon et al. 2010). Again the choice of a suitable, i.e. economically viable, catch crop strongly depends on the location of the arable land and species. Sudan grass for instance has quite a promising potential in the biogas value chain, but is very sensitive to cold temperature. In contrast at warm and dry locations it often even has an advantage compared to the cultivation of maize (Roller et al. 2012)

### 2.3.2 Literature review

Different international projects have already made an effort to summarize the numerous national and international study results regarding the assessment of this feedstock category’s availability and potential: the Biomass Energy Europe (BEE) project “Status of biomass resource assessment” for instance gives a comprehensive overview of different national and particularly international studies on this topic. The respective project report summarizes the results of the analysis of selected biomass resource assessments that cover different biomass categories and locations. The aim was to identify the major differences and discrepancies of the various approaches and the respective results, and to provide quantitative and qualitative information on the total biomass resource potentials for energy production in Europe. It was further the objective to improve the accuracy and comparability of future biomass resource assessments by reducing heterogeneity, increasing harmonization and exchanging knowledge. (N. Rettenmaier, Schorb, and Köppen 2010).

Another review paper on Sustainable supply of “non-food biomass for a resource efficient bioeconomy” was produced in the context of the international FP 7 project S2Biom (Khawaja and Janssen 2014). The project’s goal is to provide an overview on the availability of sustainable non-food biomass at local, regional and pan European for EU-28, Western Balkans, Moldova, Turkey and Ukraine. A comprehensive database and the corresponding web-based tool provide a good, well visualized overview on feedstock potentials.

Many other studies have estimated the potential of crop residues for bioenergy in addition to other residues. Using different calculation bases the resulting data on feedstock supply partly varies significantly  and was summarized in the study by (Monforti et al. 2013)) examining “the possible contribution of agricultural crop residues to renewable energy targets in Europe”. Besides relying on different calculation bases, the variations strongly depend on crop type cultivation, changing market conditions, as well as on competitive uses of agricultural residues, including the different energy uses of biomass (heat, electricity generation, and biofuels), biochemical and other bio-products. In

2014 the authors pursued a slightly different approach when examining and discussing the topic of optimal energy use of agricultural crop residues in Europe taking into account the conservation of soil fertility (Monforti et al. 2014).

A study published in the International Journal of Integrated Waste Management, Science & Technology assessed the availability of 8 crop residues (from wheat, barley, oats, rye, rice, maize, sunflower and rapeseed) in the EU-27 (Scarlat, Martinov, and Dallemand 2010). The amount of crop residues that can be used for bioenergy production has been estimated taking into account the existing environmental constraints for collection and competitive uses in the livestock sector or for horticulture/mushroom production.

A study by ICCT (International Council on Clean Transportation) assessed the total crop residue production and the current net availability of crop residues for bioenergy. They based their calculations on FAOSTAT data on yields and total annual production of these crops from 2002–2011(Searle and Malins 2013).  FAO Stat data (Food and Agriculture Organization of the United Nations, Regional Office for Europe and Central Asia 2014) are regularly updated and serve as reference for many other research projects that focus on biomass/ bio-waste availability.

In 2011, the IEE project EUBIONET 3 assessed the amount of unexploited biomass sources in Europe that could potentially be used for bioenergy purposes. According to this report the largest source of biomass residues in Southern European countries (Greece, Italy, Spain and Portugal) come from the olive industry (Hinge et al. 2011). In this region, the utilization of olive waste is growing rapidly as well as the one of nut shell representing an interesting potential as sustainable biomass for energetic exploitation. The assessments also showed that in Germany straw has the biggest potential regarding biomass residues. However, according to the study's definition, straw doesn't count as "new and unexploited biomass" and therefore was not further investigated. Other residues like horse litter, sunflower seed shell and sunflower press cake pellets, reed, grass (hay), kernels of stone fruits and viniculture residues have been taken into account instead. Restrictions in the assessments were encountered regarding the availability of national data on the amount of these residues. Due to the already high utilization rate of biomass, the feedstock market is getting increasingly competitive and companies don't want to let (potential) competitors know how much biomass they process. In the Netherlands for example only one still unexploited biomass was identified at that time: chicken manure (Hinge et al. 2011).

IEA Bionergy Task 40 has published country reports, which identify domestic biomass resources in the member countries, among others Germany (updated in 2014), Italy, Austria and UK (published in 2011), and describe its current use, trends, and main utilisations. The reports also include presentations of drivers, barriers & opportunities of bioenergy production in these counties. The latest reports can be found here: http://www.bioenergytrade.org/publications.html

Country reports, more specifically national roadmaps for the development of the biomethane sector, were also developed in the framework of the project GreenGasGrids. However, not all of these reports include a dedicated chapter on biomass availability, use and potentials. Some information on this topic can be found in the Hungarian, French, Austrian and British roadmap.

http://www.greengasgrids.eu/market-platform/national-roadmaps.html

Regarding other relevant international studies, one that was published by the Oxford Institute for Energy Studies in 2012 should also be mentioned. The study called "Perspectives for Biogas in

Europe by Floris van Foreest describes, among others, European and Global biomass supply and demand, types of biomass and its use for biogas production as well as biomass potentials (van Foreest 2012)

In Germany, the Agency for Renewable Resources (AEE) produced a literature review of 16 international studies on bioenergy potentials and biomass origins published between 2003 and 2014 and compared their results (AEE - Agentur für Erneuerbare Energien 2014). Regarding the assessment of international biomass potentials, they particularly highlight an analysis conducted by the German Biomass Research Centre (DBFZ) in 2010. The respective report includes estimations of potentials of agricultural area as well as potentials of wastes and residues (Seyfert et al. 2010).

Furthermore, the DBFZ produced another, more recent study that specifically focuses on the assessment of biomass potentials of wastes and residues. The study summarizes the results of a project that was finished in 2015 and which was funded by the German Ministry of Food and Agriculture. The study describes the state of knowledge regarding the current German biomass potentials. Due to the participation of several other institutions and the development on a suitable data structure, a unique database on this topic was established. A comprehensive data collection was implemented for 93 different biomass types. In addition the data was evaluated and data gaps were identified. The assessment revealed that agricultural by-products and residues as well as residues from forestry account for the majority of the bio-waste and residue materials (Brosowski et al. 2015).

## 3. OVERVIEW OF SELECTED DATA SOURCES

In the following, a synoptical table containing all mentioned literature sources will give an overview on the amount of information that was found in this survey regarding the different described feedstock categories. It is further differentiated between national and international studies to allow an evaluation of the coverage of this topic in the concerned countries. In general it can be stated that international approaches are much more frequent in the identified studies.

Most of the references listed in the table include a short note on the general focus of the respective literature source making the overview more informative for the reader and easier to classify. Studies were included that mainly concentrate on describing the biomass potential whereas others rather elaborate on the biomass use. Some of the listed studies are literature reviews themselves, which is marked in the table as well. In addition, 5 data portals about the general use of biomass, the concerned feedstocks included, and the specific energy content of the material.

Focusing on the countries represented in BIOSURF, national approaches and analysis for determining the amount and type of input material in biogas plants further exist in:

- United Kingdom: AD (official information portal on anaerobic digestion of the Department for Environment Food and Rural Affairs and the Department of Climate and Energy Change) - (Http://www.biogas-Info.co.uk/ n.d.) providing a biogas map with details of all operational biogas plants with links to websites and information about type of biomass where available (Http://www.biogas-Info.co.uk/ad-Map.html n.d.)
- Germany: DBFZ (Deutsches Biomasseforschungszentrum) – carry out the EEG-Monitoring. The report include an analysis of utilized biomass categories (Scheftelowitz et al. 2014).
- Italy: Etaflorence – analyzed feedstock for biogas in Italy within the IEA Bioenergy Task 40 (Cocchi 2012)
- Austria: Energy-Control Austria – Ökostrombericht (Proidl et al. 2012) contain data about feedstock used in biogas plants. Further biomass utilization pathways and the amount of used feedstocks should be identified to estimate unused biomass potentials.

It must be emphasised that it is not claimed that the following tabular overview and the previous elaboration reflect an exhaustive list of information and data on this topic. Since the most current and best known studies and data portal links are included, it will nevertheless provide a good impression on the coverage of this topic, showing existing gaps, where further assessments and data collection should be encouraged, possibly in the framework of future projects.

***Table 3-1***: *Literature References on the topic of waste and residue biomass use and its potentials in selected European countries*

| Reference | Feedstock Category | | | Quantity | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Animal Waste | Other Waste Materials | Residues | DE | IT | HU | A | F | UK | EU |
| **(https://www.ecn.nl/phyllis2/ n.d.)** *Database calorific values* | x | x | x | | | | | | | x |
| **(Http://www.atlantebiomasse.enea.it/ n.d.);** *Biomass potential; geoportal* | x | | | | x | | | | | |
| **(Http://ec.europa.eu/eurostat/de/data/database n.d.)**; *Database; NUTS2-level* | x | | | x | x | x | x | x | x | x |
| **(http://faostat3.fao.org/browse/Q/*/E n.d.);** *Database; Country-level* | x | | | x | x | x | x | x | x | x |
| **(Http://iung.neogis.pl/geoportal/ n.d.)**; *Biomass potential; Geoportal* | x | x | x | x | x | x | x | x | x | x |
| BMVBS **(Seyfert et al. 2010)** | x | x | x | x | x | x | x | x | x | x |
| **(Elbersen, Startisky, Hengeveld, Schellhaas, and Neaff 2012)** | x | x | x | x | x | x | x | x | x | x |
| **(European Environment Agency 2006)** | x | x | x | x | x | x | x | x | x | x |
| **(Foged et al. 2012)** | x | | | x | x | x | x | x | x | x |
| **(Holm-Nielsen, Al Seadi, and Oleskowicz-Popiel 2009)***; Biomass potential 2003* | x | | | x | x | x | x | x | x | x |
| **(Pudelko, Borzecka-Walker, and Faber 2013)** | x | x | x | x | x | x | x | x | x | x |
| **(ARUP URS Consortium 2014)** | x | x | x | | | | | | x | x |
| **(Brosowski et al. 2015)** | x | x | x | x | | | | | | |
| **(Kaltschmitt et al. 2003)** | x | x | x | x | | | | | | |
| **(Majer et al. 2013)** | x | x | x | x | | | | | | |
| **(Mühlenhoff 2013)***; review based on:* **(BMVBS 2010)** | x | x | x | x | | | | | | |

| Reference | Feedstock Category | | | Quantity | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Animal Waste | Other Waste Materials | Residues | DE | IT | HU | A | F | UK | EU |
| **(Universität Rostock, Institut für Energetik und Umwelt gGmbH, and Bundesanstalt für Landwirtschaft 2007)**; *Biomass potential 2004* | x | | x | x | | | | | | |
| **(Öko-Institut et al. 2004)**; *Biomass potential, 2000, 2010, 2020, 2030; scenarios* | x | x | x | x | | | | | | |
| *Eurostat Municipal Wastes:* http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tsdpc240&language=de | | x | | x | x | x | x | x | x | x |
| **Waste framework directive 2008/98/EC** | | x | | | | | | | | x |
| **Future steps in bio-waste management in the EU SEC/2010/577** | | x | | | | | | | | x |
| **Waste statistics EC 2150/2002 amended through EC 849/2010** | | x | | | | | | | | x |
| **Landfill directive 1999/31/EC** | | x | | | | | | | | x |
| **(Zeller et al. 2011)** | | | x | x | | | | | | |
| **(DEFRA 2011)** | x | x | | | | | | | x | |
| **(Howes et al. 2011)** | x | x | | | | | | | x | |
| **(Rosillo-Calle and Galligani 2011)** | x | x | | | | | | | x | |
| **(Slade, Bauen, and Gross 2010)** | x | x | | | | | | | x | |
| **(ADEME 2013)** | x | | | | | | | x | | |
| **(MIPAAF 2008)** | x | | | | x | | | | | |
| **(Colonna, Alfano, and Gaeta 2009)** | x | | | | x | | | | | |
| **(Kalt, Matzenberger, and Kranzl 2011)** | x | | x | | | | x | | | |

| Reference | Feedstock Category | | | Quantity | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Animal Waste | Other Waste Materials | Residues | DE | IT | HU | A | F | UK | EU |
| (Kranzl et al. 2008) | x | | x | | | | x | | | |
| (Kern 2012) | | x | x | x | | | | | | |
| (Renewable Energy: National Renewable Energy Action Plan, 2010 - 2020 2011); | x | | | | | x | | | | |
| (Szunyog 2008) | x | x | x | | | x | | | | |
| (Nils Rettenmaier, Schorb, and Köppen 2010); *Review* | x | x | x | x | | | | | | x |
| (Thrän et al. 2004); *Biomass potential* | x | x | x | x | x | x | x | x | x | x |
| (Scarlat, Martinov, and Dallemand 2010) | | x | | | | | | | | x |
| (Agentur für Erneuerbare Energien (AEE) 2013) | x | | | x | | | | | | |
| (Khawaja and Janssen 2014) | | | x | | | | | | | x |
| (Deutscher Verband für Landschaftspflege (DVL) e.V. 2014) | x | | | x | | | | | | |
| (Bloomberg New Energy Finance 2012) | x | x | x | | | | | | | x |
| (Helmer and Böller 2010) | | | x | x | | | | | | |
| (Universität Stuttgart 2012) | | x | | x | | | | | | |
| (Lampert, Reisinger, and Zethner 2014) | | x | x | | | | x | | | |
| (FABbiogas project 2014) | | x | x | x | x | | x | x | | x |
| (Al Seadi et al. 2013) | | x | | | | | | | | x |
| (Kranert et al. 2012) | | x | | x | | | | | | |
| (Roller et al. 2012) | | | x | x | | | | | | |
| (Searle and Malins 2013) | | x | x | | | | | | | x |
| (Monforti et al. 2013) | | | x | | | | | | | x |

| Reference | Feedstock Category | | | Quantity | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Animal Waste | Other Waste Materials | Residues | DE | IT | HU | A | F | UK | EU |
| (Monforti et al. 2014) | | | x | | | | | | | x |
| (Hinge et al. 2011) | x | x | x | | | | | | | x |
| (van Foreest 2012) | x | x | x | | | | | | | x |
| (Food and Agriculture Organization of the United Nations, Regional Office for Europe and Central Asia 2014) | x | x | x | | | | | | | x |
| (Leible et al. 2015) | | | x | x | | | | | | |
| (GreenGasGrid 2013a) | x | x | x | | | x | | | | |
| (GreenGasGrid 2014a) | x | x | x | | | | x | | | |
| (GreenGasGrid 2014b) | x | x | x | | | | | | x | |
| (GreenGasGrid 2013b) | x | x | x | | | | | x | | |
| (AEE - Agentur für Erneuerbare Energien 2014) | x | x | x | x | | | | | | x |
| (Birkmose, Foged, and Hinge 2007); *Biomass utilization* | x | | | x | x | | x | | x | x |
| (Http://www.biogaspartner.de/europa.html n.d.); *Biomass utilization, geoportal* | | | | x | x | x | x | x | x | x |
| (Http://www.biogas-Info.co.uk/ n.d.); *Biomass utilization, geoportal* | | | | | | | | | x | |
| (Scheftelowitz et al. 2014); *Biomass utilization* | | | | x | | | | | | |
| (Cocchi 2012); *Biomass utilization* | | | | | x | | | | | |
| (Proidl et al. 2012); *Biomass utilization* | | | | | | | x | | | |

## 4. CONCLUSIONS

The category of biogenic residues and wastes cover a wide range of materials, and just a selection of those has been assessed in this report focusing on reviewing existing literature sources on their availability, use and potential.

Studies about biomass potentials usually calculate different levels of potential (theoretical, technical or sustainable potential) and consider different parameters like economic and ecological aspects, e.g. soil fertility (humus layer, nitrate input), legal restrictions, biodiversity and nature conservation targets. The units of measurements differ between studies (fresh weight, dry weight, m³ biogas, PJ, t, toe) and are partially difficult to convert. Therefore, a comparison of biomass potentials between countries is challenging and most useful in analysis of European studies rather than national studies. However, national studies integrate stronger regional aspects (e.g. humus balance) in their analyses than European studies and provide to some extent better spatial resolution (e.g. straw potential on NUTS3-level in (Pudelko, Borzecka-Walker, and Faber 2013; Zeller et al. 2011).

Most identified studies in this survey have been conducted on EU-Member States level and mostly include the countries represented by the participants in the BIOSURF project (Italy, Austria, Germany, France, Hungary, UK). These studies, partly in form of “roadmaps“, often make projections for different scenarios in the future, e.g. 2020. Regarding national studies, the result of the survey was quite diverse (focus was on the countries represented in BIOSURF):  data on availability, use and potential of biogenic residue and waste materials are scarce for Hungary, France and Italy, more frequent for Austria and the United Kingdom and best covered in Germany (**Figure 4-1**).

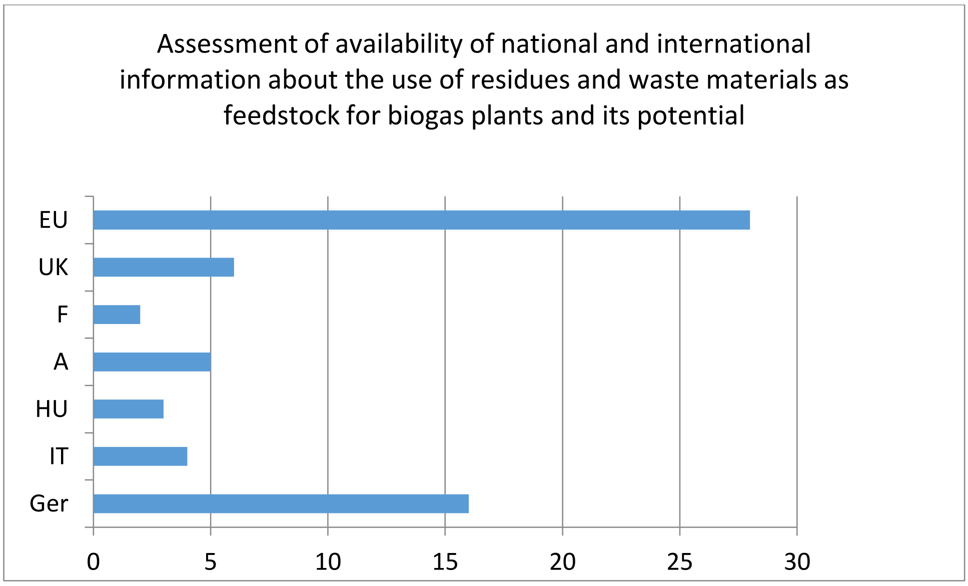



***Figure 4-1**: Literature sources about availability and potential of using residue and waste materials as feedstock for biogas plants*

Studies about biogenic residue and waste materials are mostly part of extensive meta studies about biomass potentials. The considered categories are heterogeneous and often differ in their designations and definitions. The calculated biomass potentials in the studies do not regard quantities already used. Data about unused quantities are not available. Base data are scarce, however individual countries conduct singular or regular monitoring about the use of specific biomasses for selected technologies (Cocchi 2012), (Proidl et al. 2012; Scheftelowitz et al. 2014).

It needs to be pointed out, though, that this report cannot claim to reflect an exhaustive list of data sources on this topic. Furthermore, some of the included studies represent a literature review themselves and do not deliver new insights or data on sustainable biomass availability, use or its potential. Since the most current and best known studies and data portal links are included, it will nevertheless provide a good impression on the coverage of this topic in different European countries, showing existing gaps. In order to reduce them further assessments and data collections should be encouraged - possibly in the framework of future projects.

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N.d. http://ec.europa.eu/eurostat/statistics-explained/index.php/Farm_structure_statistics.

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