BIOREFINE

Recycling inorganic chemicals from agro- and bio-industrial waste streams

Project/Contract number: 320J - Biorefine

Document number: BIOREFINE – WP2 – A4 – P2 – D

Inventory of wastes produced in Belgium, Germany, France, the Netherlands and the United Kingdom

Date: 16/11/2015

Start date of project: 1 May 2011 Duration: 56 months

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Project funded by the European Regional Development Fund through INTERREG IV B

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1 Glossary

AFF: Agriculture, Fishing and Forestry

AG: Agriculture

As: Arsenic

AU: Agricultural Use

AVW: Animal and Vegetal wastes

C/N ratio: Carbon-to-Nitrogen ratio

C (%): Carbon content

CaO (%): Calcium content expressed in calcium oxide

Cd: Cadmium

CD: Composting/Anaerobic Digestion

CMW: Chemical and Medical Wastes

Co: Cobalt

COA: Compost and Other Applications

Cr: Chromium

CS: Common Sludges

Cu: Copper

DL: Deposit onto or into Land

DM (%): Dry Matter content

EEG: Renewable Energy Act

EQ: Equipment

EU: European Union

EU-28: European Union counting 28 countries

H: Households

Hg: Mercury

I: Incineration

ID: Incineration/Disposal

IER: Incineration/Energy Recovery

IES: Industrial Effluent Sludges

K: Potassium

K_2O (%): Potassium content expressed in potassium oxide

L: Landfilling

LA: Landfill

LD: Landfill/Disposal

LSU: Livestock Unit

LTRW: Land Treatment and Release into Water bodies

MFBT: Manufacture of Food products, Beverages and Tobacco products

MgO (%): Magnesium content expressed in magnesium oxide

Mha: Million hectares

MLSU: Million Livestock Units

Mo: Molybdenum

MOW: Mixed Ordinary Wastes

MP: Manufacture of Paper and paper products; printing and reproduction of recorded media

MR: Material Recycling

MSW: Mineral and Solidified Wastes

MT: Million Tonnes

MWCS: Manufacture of Wood and of products of wood and Cork, except furniture; manufacture of articles of Straw and plaiting materials

N: Nitrogen

Ni: Nickel

N_{NH4} (%): Ammoniacal Nitrogen content

N_{NO3} (%): Nitrate content

N_{tot} (%): Total Nitrogen content

O: Others, Other techniques

P: Phosphorus

P_2O_5 (%): Phosphorus content expressed in phosphorus pentoxide

Pb: Lead

PCB: Poly-Chlorinated Biphenyls

PKH: Production in kg per capita

PT: Production in Tonnes

R\ER: Recovery other than Energy Recovery

R\ER-B: Backfilling

R\ERB: Recovery other than Energy Recovery, excluding Backfilling

RW: Recyclable Wastes

S: Services

SE: Sewage

SLW: Sludge and Liquid Wastes from waste treatment

TNH: Total Number of agricultural Holdings

TNHF: Total Number of agricultural Holdings possessing storage Facilities

UAA: Utilized Agricultural Area

UWWT: Urban Wastewater Treatment

WCTD: Waste Collection, Treatment and Disposal activities, materials recovery

WRW: Water collection, treatment and supply, sewerage, Remediation activities and other Waste management services

WWT: Wastewater Treatment

WWTP: Wastewater Treatment Plant

Zn: Zinc

2 General introduction

It is essential for nutrients to be available to ensure sufficient food production. Due to the worldwide growing food demand, the need for fertilisers is increasing. In addition, minerals are required in other sectors such as in the chemical sector. At the same time, there are regions in North-West Europe (NWE) that suffer from a surplus of nutrients present in waste streams. This surplus can be harmful to environment. In this context, considering wastes as new nutrient resources could contribute to solving the problems of waste surpluses and nutrients demand.

The waste flows are significant and some of them contain substantial concentrations in nitrogen, phosphorus and potassium, well known as key elements in agriculture. Manure, slurry, digestate, sewage sludge, household wastes, ashes and industrial wastes contain these nutrients but also pollutants such as heavy metals. The use of such materials as nutrients' sources requires the extraction of nutrients in a suitable form, usable by plants.

The presence of pollutants in wastes causes legal problems. The extraction of nutrients from wastes and the production of fertilisers from them require a purification step of pollutants during the process. These pollutants must respect the legal constraints applied to fertilisers in all EU member states. The legal status of waste is another constraint, because a material coming from wastes will be seen as waste as well unless it can be proven that it qualifies for use as a fertiliser. Transnational transport of wastes is also problematic between regions and countries.

The present report does not consider the legal aspects of waste recovering as fertilisers but focuses on the opportunities relating to wastes considering their composition and production. Most of the data listed in this report comes from Eurostat®.

3 Global waste production in Europe

It has been established that the overall European solid waste production amounts to about four billion tonnes per year while the European Union generates about 2 billion tonnes (Hillstrom and Collier Hillstrom, 2003; Morselli et al., 2009). The mean waste generation is not identical in the countries of the EU-15 (France, Germany, Italy, the Netherlands, Belgium, Luxemburg, Ireland, the United Kingdom, Denmark, Greece, Spain, Portugal, Finland, Sweden, Austria) and in the other countries that joined EU after 1995 (Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Hungary, Slovenia, Cyprus, Malta, Bulgaria, Romania, Croatia). A generalized recycling trend has been observed in all countries and the use of landfills has been decreasing from 1995. The basic principles which are now applied in the field of wastes were included in the Sixth Environmental Action Programme of the EU "Environment 2010: Our future, Our choice". This programme is based on major observations:

- Pollution caused by transport, agricultural activities, industrial processes, municipal and industrial waste management is the cause of a poor environmental quality, contributing to a negative impact on human health.

- Our planet has a limited capacity to cope with resources demand and wastes resulting from their use. Negative effects have been identified and are bound to metal, mineral and hydrocarbon consumption.
- The European Union produces a growing volume of wastes, coupled with a loss of land and resources and a pollution increase.
- A significant part of waste must be seen as hazardous (Morselli et al., 2009).

Consequently, it has become necessary to apply environment-friendly techniques and processes to wastes. EU waste management policies are now aiming to reduce the environmental and health impacts of wastes. The final objectives are to reduce the amount of waste generated and the promotion of recycling methods.

In 2008, the total amount of waste generated in the EU-27 reached a value of 2.62 billion tonnes, which corresponds to 5.2 tonnes of waste per capita. The levels of waste production vary considerably from country to country, with a minimal value of 660 kg/cap in Latvia and a maximal value of 37,528 kg/cap in Bulgaria. Those differences can be explained by the economic and urban structure and the environmental practices which are specific to each member state. **Figure 1** shows the total waste production in European countries in 2012.

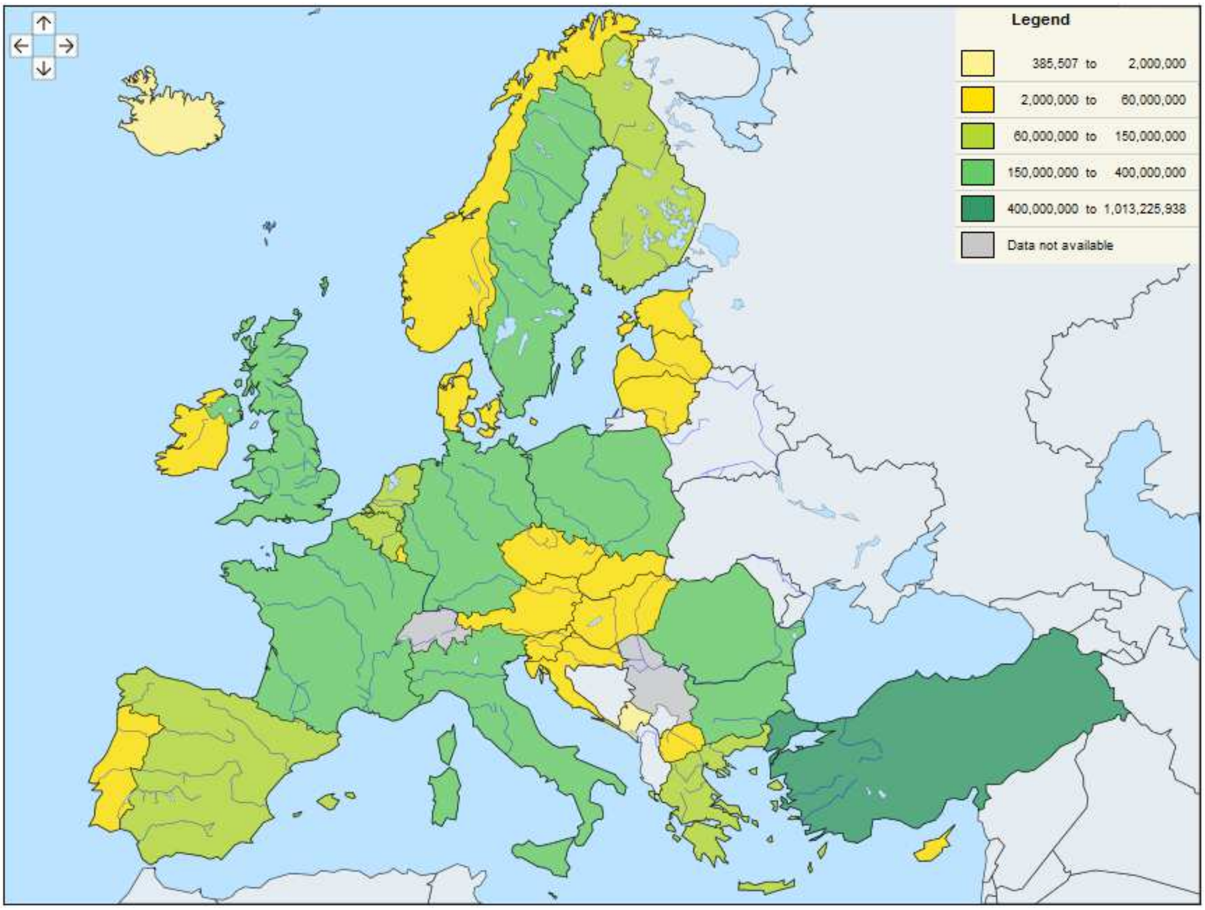

Figure 1: Total waste production (2012) in European countries in tonnes. The following categories are considered: chemical and medical wastes, recyclable wastes (metallic, glass, paper, cardboard, rubber, plastic, wood and textile wastes excluding wastes containing PCB), equipment (waste containing PCB and discarded equipment), vegetal and animal wastes (animal and mixed food waste, vegetal wastes, animal faeces, urine and manure), mixed ordinary wastes (household and similar wastes, mixed and undifferentiated materials, sorting residues), common sludges, mineral and solidified wastes.

Source: EUROSTAT®

The minimal waste production corresponds to Montenegro, while the maximal production relates to Turkey. In 2012, Belgium, France, Germany, the Netherlands and the United Kingdom respectively generated 68, 345, 368, 124 and 241 MT of wastes. The BioRefine project involved these five countries and this report will focus on them.

The different amounts of waste produced all over EU-28 are shown in **Figures 2**, **3, 4** and **5** with detailed information about Belgium, Germany, the United Kingdom, the Netherlands and France. Here, we focus on the categories which can have a key role in the field of nutrient recovery, and considered non-hazardous. **Figures 2** and **3** relate to the generation of waste by economic activity and highlight the most relevant activities as regards nutrient recovery, while **Figures 4** and **5** focus on some specific wastes which can be considered to be nutrient sources.

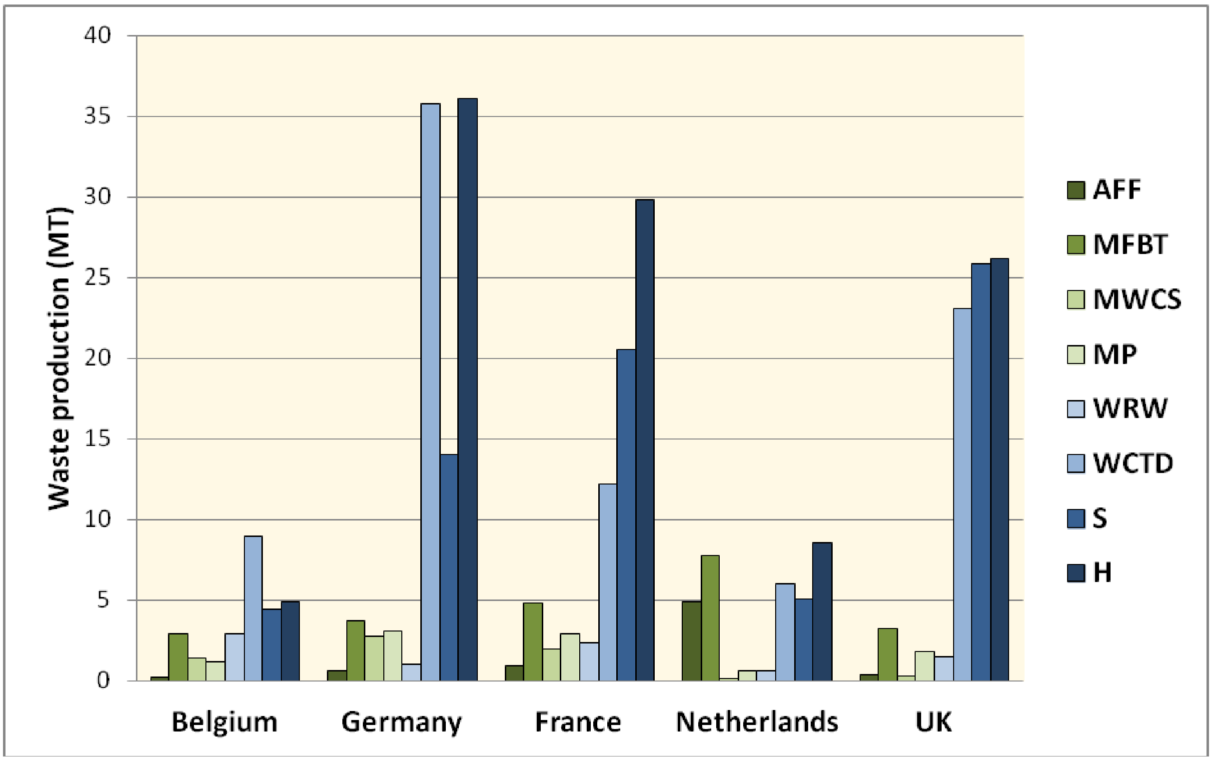

Figure 2: Waste production in Belgium, Germany, France, the Netherlands and the United Kingdom in 2012 according to economic activities expressed in million tonnes (non-hazardous wastes). The following activities are considered: Agriculture, Fishing and Forestry (AFF); Manufacture of Food products, Beverages and Tobacco products (MFBT); Manufacture of Wood and of products made of wood and Cork, except furniture; manufacture of articles made of Straw and plaiting materials (MWCS); Manufacture of Paper and paper products; printing and reproduction of recorded media (MP); Water collection, treatment and supply, sewerage, Remediation activities and other Waste management services (WRW); Waste Collection, Treatment and Disposal activities, materials recovery (WCTD); Services (S); Households (H).

Source: data collected from EUROSTAT®

Belgium generates the lowest quantities of wastes in the specific categories which are highlighted here, but it also has the smallest population (about 11 million people in 2015). Household wastes are predominant in the five countries and it must be noted that WCTD activities are quite developed in all of them. The Netherlands have good opportunities with the highest production of wastes coming from agriculture, fishing and forestry, with a population of about 17 million people in 2015.

Germany, France and the UK generate the highest amounts of wastes with populations of about 81, 67 and 65 million people. Considering the categories that have been chosen because of their nutrient contents, these three countries mainly generate household wastes and wastes coming from services, but considerable amounts of wastes are collected, treated and recycled (WCTD category). "Services" are wastes generated by many types of activities: wholesale and retail trade, repair of motor vehicles, motorcycles, transportation and storage, accommodation and food service activities, information and communication, financial and insurance activities, real estate activities, professional, scientific and technical activities, administrative and support service activities, public administration and defence, compulsory social security, education, human health and social work activities, arts, entertainment and recreation, activities of households and employers, undifferentiated goods, services producing activities of households for own use, activities of extraterritorial organisations and bodies, and some other services (Eurostat, 2010). Consequently, the complexity of the figures which relate to this category must be taken into account. In **Figure 2**, the figures are expressed in absolute values (tonnes of materials). **Figure 3** expresses the data according to the respective populations.

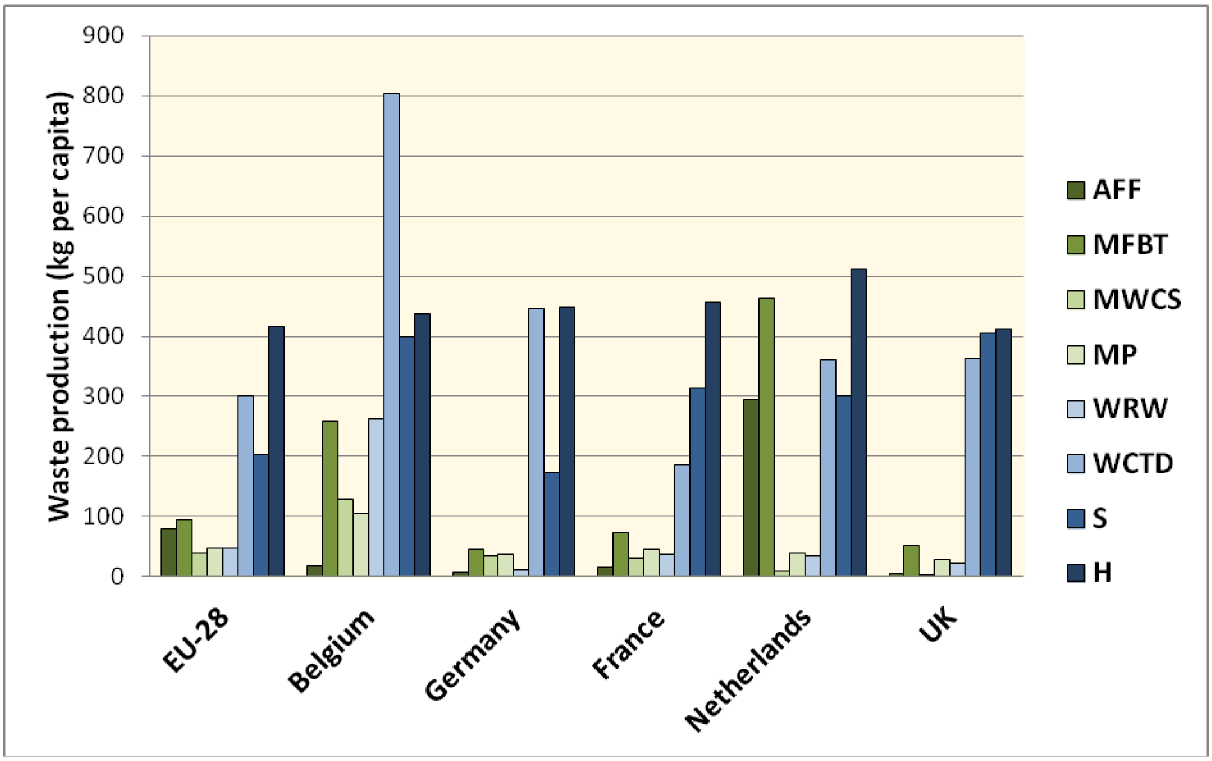

Figure 3: Waste production in EU-28, Belgium, Germany, France, the Netherlands and the United Kingdom in 2012 according to economic activities, expressed in kg per capita (non-hazardous wastes). The following activities are considered: Agriculture, Fishing and Forestry (AFF); Manufacture of Food products, Beverages and Tobacco products (MFBT); Manufacture of Wood and of products of wood and Cork, except furniture; manufacture of articles of Straw and plaiting materials (MWCS); Manufacture of Paper and paper products; printing and reproduction of recorded media (MP); Water collection, treatment and supply, sewerage, Remediation activities and other Waste management services (WRW); Waste Collection, Treatment and Disposal activities, materials recovery (WCTD); Services (S); Households (H).

Source: data collected from EUROSTAT®

Figure 3 shows a stability of production of household wastes in the 28 European countries. However, **Figure 3** also confirms a relatively large production of wastes coming from agriculture, forestry and fishing in the Netherlands, in comparison with the other countries and the European mean value. The high value relating to the wastes generated by the industries which relate to food products, beverages and tobacco products in the Netherlands should also be highlighted. In Germany, France, the Netherlands and the United Kingdom, the amounts of wastes produced by paper industry (MP) and water collection and treatment (WRW) are lower than the European mean value. In Belgium, the waste productions relating to the MFBT, MWCS, MP, WRW and S activities tend to exceed the European mean values, which means that this country shows the highest waste productions expressed in kg per capita for these categories compared to Germany, France, the Netherlands and the UK.

It must be noted that two major activities generate high levels of waste in EU-28: construction and mining/quarrying. The majority of wastes generated by those activities are excavated earth, road construction waste, demolition waste, dredging spoil, waste rocks, tailings, etc. These wastes are mainly composed of mineral materials but do not offer opportunities in respect of nutrient recovery. Consequently, these wastes were not considered in the figures.

The production of wastes can also be considered according to their nature. Here, we will focus on some non-hazardous wastes containing nutrients (nitrogen, N; phosphorus, P; potassium, K): Industrial Effluent Sludges (IES), Sludges and Liquid Wastes from waste treatment (SLW), Animal and Vegetal Wastes (AVW), Mixed Ordinary Wastes (MOW) and Common Sludges (CS). IES are sludges and solid residues from industrial wastewater treatment, including external and/or physical treatment, solid and liquid wastes from soil and groundwater remediation, sludges from boiler cleaning, wastes from cooling water preparation and cooling columns and drilling mud. SLW include wastes from the physicochemical treatment of hazardous wastes, liquids and sludges from the anaerobic treatment of waste (digestate), landfill leachate and effluent treatment sludges from oil regeneration. AVW corresponds to animal and mixed food waste, vegetal wastes, animal faeces, manure and urine. MOW is composed of household and similar wastes, mixed and undifferentiated materials and sorting residues. CS is composed of wastewater treatment sludges from municipal sewerage water and organic sludges from food preparation and processing. They mainly originate from households and industrial branches with organic wastewater (mainly pulp and paper as well as food preparation and processing). They can also occur in wastewater treatment plants or in the anaerobic treatment of waste. Common sludges are considered non-hazardous (Eurostat, 2010).

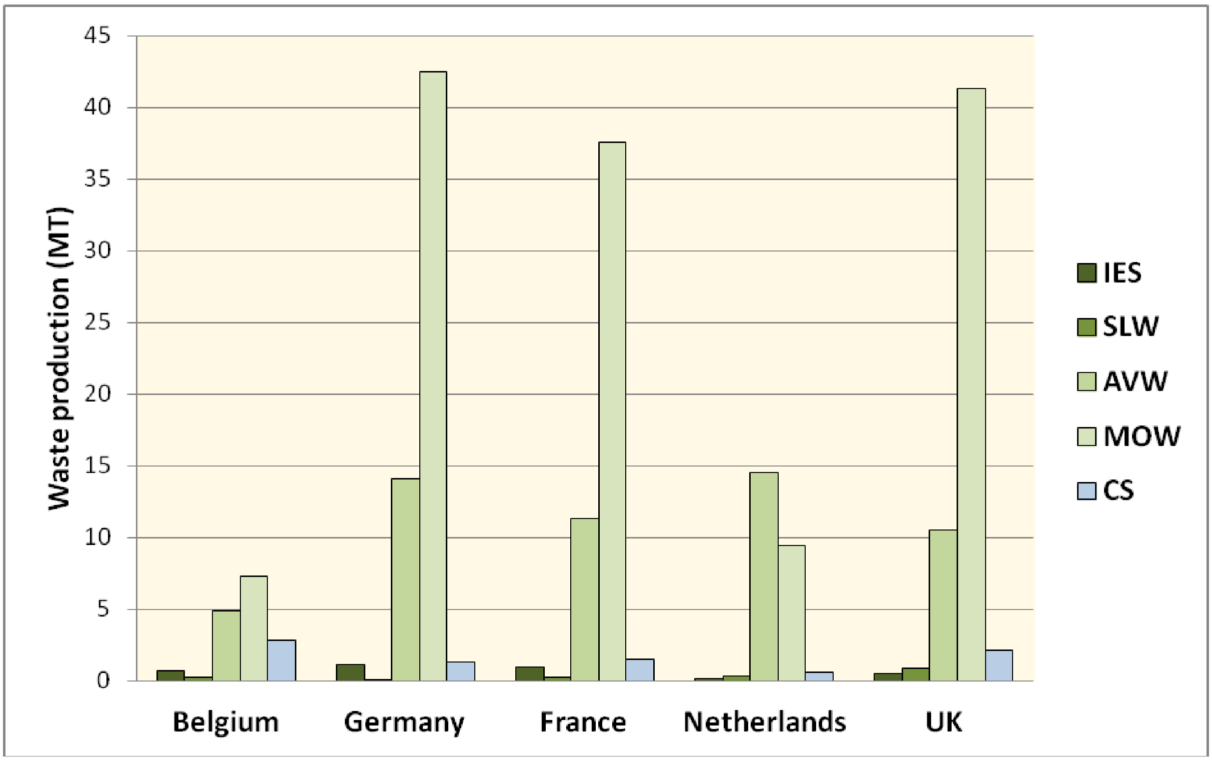

Figure 4: Waste production in Belgium, Germany, France, the Netherlands and the United Kingdom in 2012 according to the type of waste expressed in million tonnes (MT) (non-hazardous wastes). The following wastes are considered: Industrial Effluent Sludges (IES), Sludges and Liquid Wastes from waste treatment (SLW), Animal and Vegetal wastes (AVW), Mixed Ordinary Wastes (MOW) and Common Sludges (CS).

Source: data collected from EUROSTAT®

Household wastes are predominant in most countries, but animal and vegetal wastes are also produced in relatively important amounts. The other wastes which correspond to the categories IES, SLW and CS are of less importance in terms of quantities. Indeed, the five countries produced about 140 MT of mixed ordinary wastes, 55 MT of animal and vegetal wastes, while the last three categories (including industrial effluent sludges, sludges and liquid wastes from waste treatment and common sludges) corresponded to a total amount of 14 MT (of wastes). These data highlight the opportunities which relate to household wastes and animal/vegetal wastes. These data can also be expressed according to the respective populations of each country (**Figure 5**).

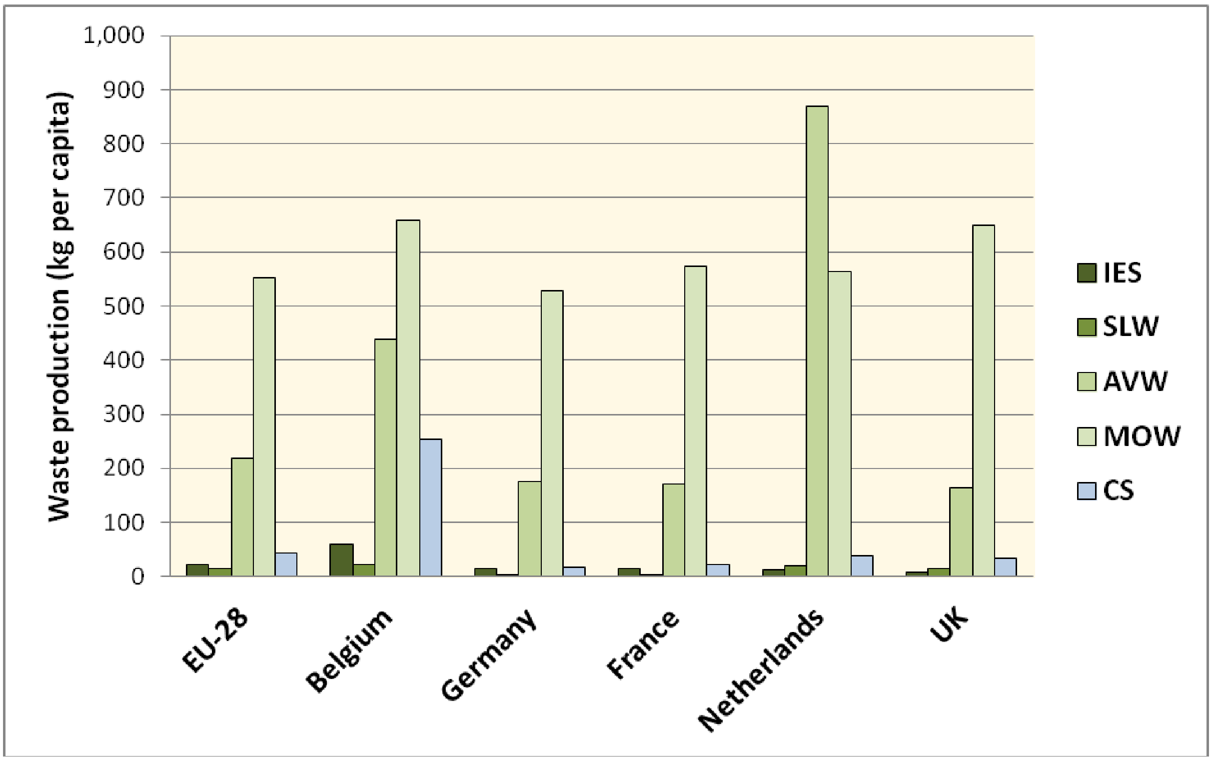

Figure 5: Waste production in Belgium, Germany, France, the Netherlands and the United Kingdom in 2012 according to the type of waste expressed in kg per capita (non-hazardous wastes). The following wastes are considered: Industrial Effluent Sludges (IES), Sludges and Liquid Wastes from waste treatment (SLW), Animal and Vegetal wastes (AVW), Mixed Ordinary Wastes (MOW) and Common Sludges (CS).

Source: data collected from EUROSTAT®

Figure 5 shows a higher waste/population ratio for industrial effluents in Belgium, while it remains quite stable in the other countries (from 8 to 15 kg waste per capita). It is also higher than the mean European value. Once again, the production of household wastes is found to be stable and close to the mean value in EU-28. Belgium and the Netherlands show a high waste/population ratio for animal and vegetal wastes, but animal wastes, especially manure and slurry, will be further discussed in the next sections. Belgium also shows the highest waste/population ratio for the production of common sludges (254 kg per capita), much higher than the mean value in EU-28 (43 kg of common sludges per capita).

Waste treatment is also dependent on the country considered. **Figure 6** shows the treatments applied to non-hazardous wastes (all classes considered) in Belgium, Germany, France, the Netherlands and the United Kingdom.

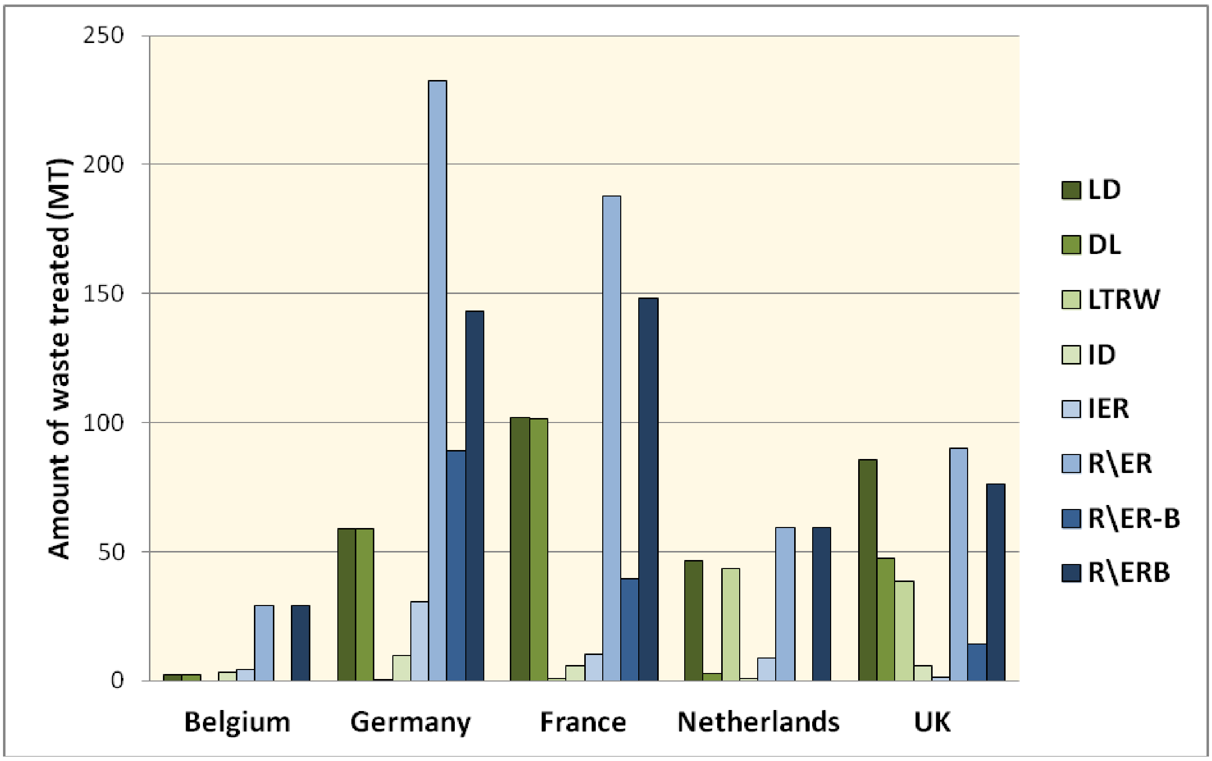

Figure 6: Waste treatment in Belgium, Germany, France, the Netherlands and the United Kingdom in 2012 expressed in million tonnes of waste. All types of non-hazardous wastes are considered. LD = Landfill/Disposal; DL = Deposit onto or into Land; LTRW = Land Treatment and Release into Water bodies; ID = Incineration/Disposal; IER = Incineration/Energy Recovery; R\ER = Recovery other than Energy Recovery; R\ER-B = Backfilling; R\ERB = Recovery other than Energy Recovery, excluding Backfilling.

Source: data collected from EUROSTAT®

LD, or Landfill and disposal correspond to different operations and include DL (Deposit into or onto Land). LD also includes land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.), deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.), surface impoundment (e.g. placement of liquid or sludgy discards into pits, ponds or lagoons, etc.), specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.), release into a water body (including seas/oceans and sea-bed insertion), and permanent storage (e.g. emplacement of containers in a mine, etc.). ID is simple waste incineration. IER is incineration with energy recovery, which means that wastes are used as fuels or other means to produce energy. R\ER corresponds to the other types of recovery, which include: solvent reclamation and regeneration, recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes), recycling/reclamation of metals and metal compounds, recycling/reclamation of other inorganic materials, regeneration of acids or bases, recovery of components used for pollution abatement, recovery of components from catalysts, oil re-refining or other reuses of oil, land treatment resulting in benefit to agriculture or ecological improvement, use of wastes obtained from energy recovery processes and backfilling. R\ER-B relates to backfilling only. Finally, R\ERB relates to all types of recovery (as in R\ER), excluding backfilling (Eurostat, 2010).

Techniques for recovery (energy and materials) from wastes are widely used in Belgium, Germany, France, the Netherlands and the UK. The practice of backfilling in Germany (89 MT) and France (40 MT) is definitely successful. Backfilling is a recovery operation where waste is used in excavated areas (such as underground mines, gravel pits) for the purpose of slope reclamation or safety or for engineering purposes in landscaping and where waste is substituted for other non-waste materials. Unfortunately, landfilling and similar activities which do not recover wastes are still widely used in all countries (2, 59, 102, 46 and 86 MT in Belgium, Germany, France, the Netherlands and the UK, respectively). It is also important to notice the wide use of incineration (with and without energy recovery) in each country, which generates ashes, usually sent to landfills or further recovered.

In this global context, the BioRefine project the objectives of which are the recovery of useful nutrients from organic wastes is justified. Some countries produce high amounts of wastes which contain recoverable nutrients for agriculture. The BioRefine project focuses on specific wastes which are known to contain notable concentrations in nitrogen, phosphorus and potassium: manure and slurry, sewage sludge, ashes, digestate, household and some industrial wastes. These materials will be further discussed in the next sections.

4 Animal wastes

4.1 Composition

Animal wastes, such as manure, slurry and spoiled straw are common residues generated by livestock production. Animal wastes have been commonly used as fertilisers in agriculture for a long time. However, raw animal residues may require specific treatments before being used as fertilisers for the following reasons:

- The farm operation can get more efficient,
- The pollution risks from manure and slurry can be reduced,
- Nuisance factors can be reduced as well, such as offensive odours,
- Hygienic concerns can be solved,
- The value of solid and liquid animal wastes in the farm can be increased (Burton, 2007).

Table 1 shows the composition of some samples of manure and slurry coming from different types of livestock. These data are only informative and were obtained from a small number of samples.

Table 1: Composition of bovine manure, bovine slurry, pig slurry and poultry manure (non-exhaustive data).

Source: Bureau d'études environnement et analyses (BEAGx), GRENeRA

Bovine manure			*Bovine slurry*		
Parameter	**Raw matter**	**Dry matter**	**Parameter**	**Raw matter**	**Dry matter**
DM (%)	20.7-43.1		DM (%)	4.54-8.04	
N_{tot} (%)	0.53-1.43	2.19-4.12	N_{tot} (%)	0.25-0.36	4.1-5.6
N_{NH4} (%)	0.1-0.30	0.36-1.13	N_{NH4} (%)	0.17-0.23	2.4-3.8
P_2O_5 (%)	0.22-0.65	1.08-2.15	P_2O_5 (%)	0.082-0.13	1.6-1.8
K_2O_t (%)	0.69-1.56	2.88-5.24	K_2O_t (%)	0.30-0.36	3.8-7
C (%)	6.80-15.1	24.7-39.8	C (%)	1.7-3.1	38.2-39.5
C/N ratio	8.3-15.6		C/N ratio	7-9.6	
Pig slurry			*Poultry manure*		
Parameter	**Raw matter**	**Dry matter**	**Parameter**	**Raw matter**	**Dry matter**
DM (%)	9.9-16.2		DM (%)	42.8	
N_{tot} (%)	0.64-0.83	4.1-7.2	N_{tot} (%)	1.49	3.5
N_{NH4} (%)	0.42-0.60	2.6-5.2	N_{NH4} (%)	0.45	1.1
P_2O_5 (%)	0.38-0.53	2.6-4.6	P_2O_5 (%)	2.72	6.4
K_2O_t (%)	0.40-0.59	2.5-5.1	K_2O_t (%)	1.76	4.1
C (%)	3.5-5.9	30.8-36.6	C (%)	12.2	28.6
C/N ratio	4.6-9.3		C/N ratio	8.2	

4.2 Production and treatment

Key parameters necessary for the assessment of animal wastes' production (including animal faeces, urine and manure) are the Utilized Agricultural Areas (UAAs), the number of holdings, the livestock and the number of holdings with storage facilities for solid dung. These key data are shown in **Figures 7** and **8**. In these figures, animal faeces, urine and manure include slurry, manure and spoiled straw stemming from agriculture. These wastes are considered non-hazardous (Eurostat, 2010).

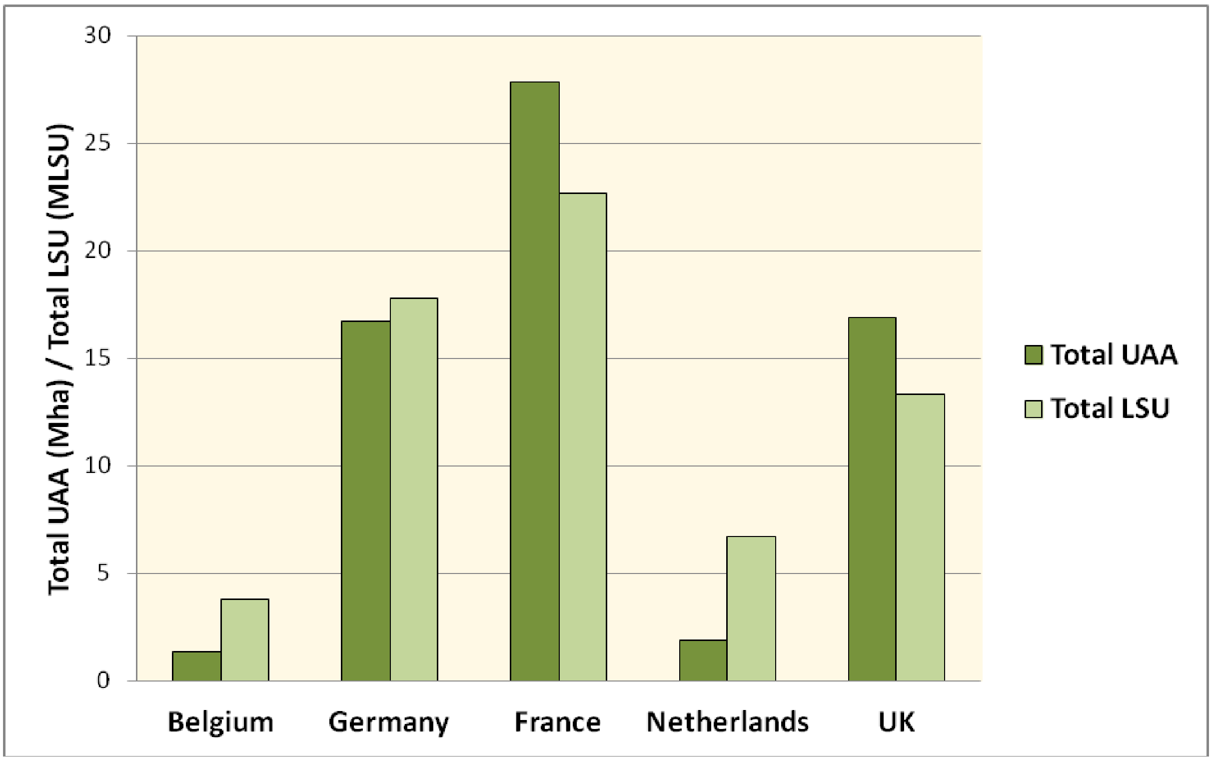

Figure 7: Total utilized agricultural areas (UAAs) and livestock units (LSUs) in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 expressed in million hectares (Mha) and million livestock units (MLSU), respectively.

Source: data collected from EUROSTAT®

Germany, France and the UK showed the highest utilized agricultural areas, with respective UAA/LSU ratios of 0.94, 1.23 and 1.27 in 2010. Belgium and the Netherlands showed lower ratios (0.36 and 0.28, respectively). These differences are explained by intensive farming in these two countries, while Germany, France and the UK focus more on cultivation. Consequently, Belgium and the Netherlands are more interested in nutrient recovery from animal wastes and potential nutrient surpluses relating to these materials.

Figure 8 shows the total numbers of agricultural holdings and holdings with storage facilities for animal dung mapped out in 2010.

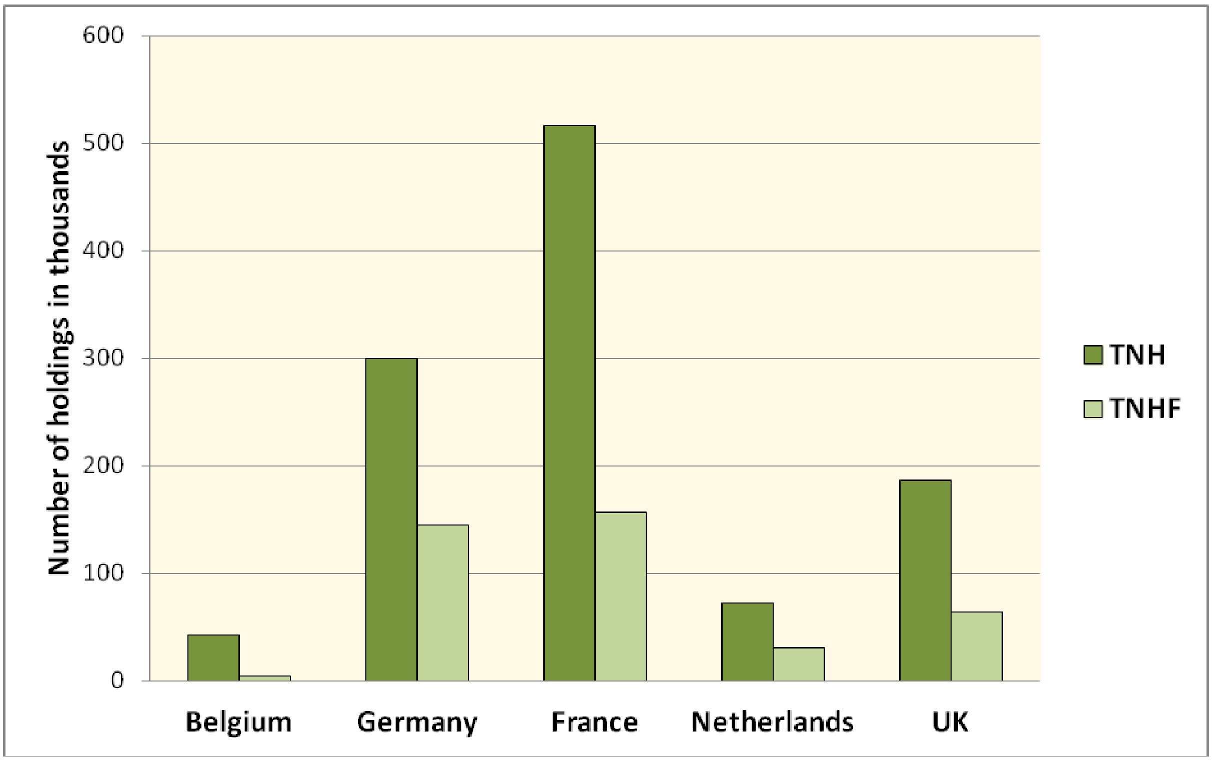

Figure 8: Total number of agricultural holdings (TNH) and of agricultural holdings possessing storage facilities (TNHF) for animal dung in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 expressed in thousands.

Source: data collected from EUROSTAT®

France possessed the highest number of agricultural holdings in 2010, with and without taking storage facilities into account. Germany showed approximately the same number of holdings with fewer storage facilities than France, while it also had far fewer agricultural holdings (about 300,000 compared to about 500,000), all categories considered. Germany, France and the United Kingdom counted a total of about 1 million agricultural holdings, while this number was estimated at 115,000 for Belgium and the Netherlands. These two countries include the lowest numbers of farms but produce relative high amounts of animal wastes in comparison to Germany, France and the UK.

The amounts of animal wastes including manure, slurry and spoiled straw produced in Belgium, Germany, France, the Netherlands and the United Kingdom are shown in **Figure 9**. Here are considered agriculture, forestry and fishing activities.

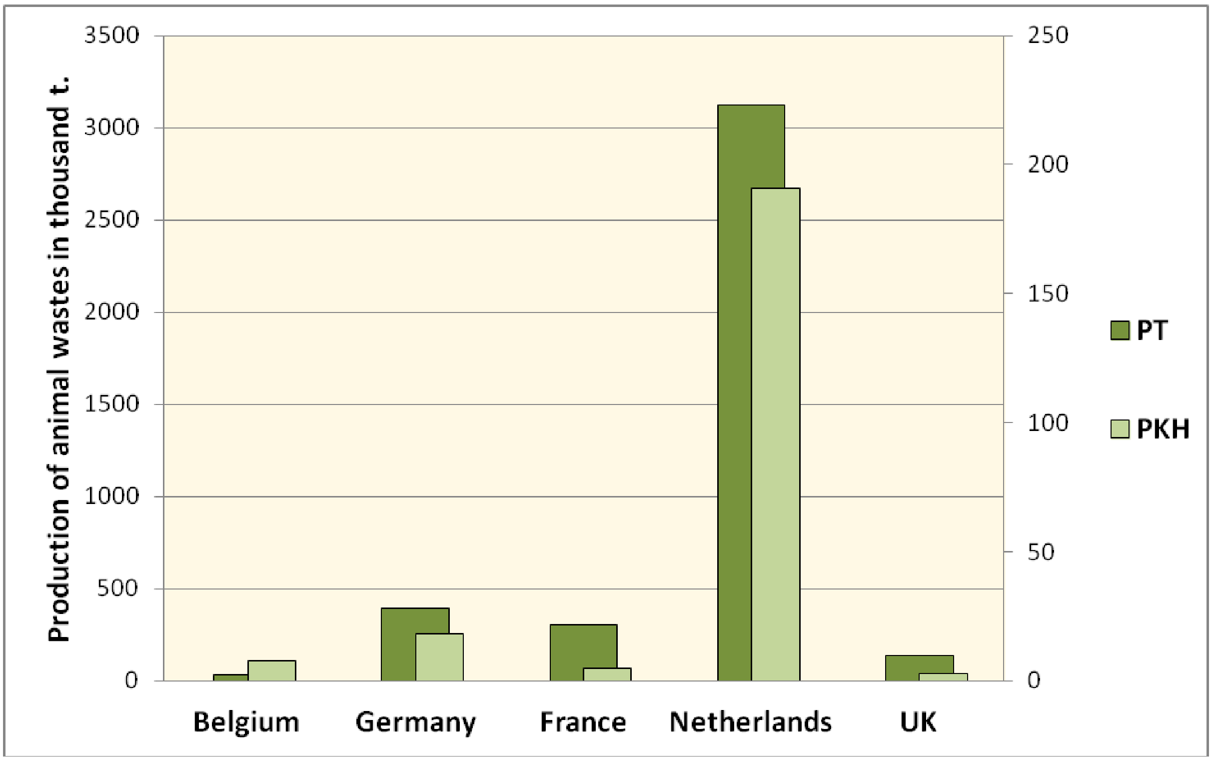

Figure 9: Total production of animal wastes (manure, slurry and spoiled straw) in Belgium, Germany, France, the Netherlands and the United Kingdom in 2012 expressed in tonnes (noted PT, in dark green, left scale) and in kg per capita (noted PKH, in light green, right scale) (non-hazardous wastes).

Source: data collected from EUROSTAT®

The highest amounts of manure and slurry are produced by the Netherlands, with a total production close to 3,000,000 tonnes in 2012. The Netherlands also showed the highest production expressed in kg per capita (191 kg per capita). Germany showed an intermediate production (18 kg per capita) while Belgium, France and the UK respectively generated 8, 5 and 3 kg per capita. Germany and France produced 393,000 and 300,000 tonnes of animal wastes in 2012 while Belgium and the UK produced 30,000 and 134,000 tonnes. **Figure 10** shows the different treatments applied to animal wastes in 2012 in Belgium, Germany, France, the Netherlands and the UK.

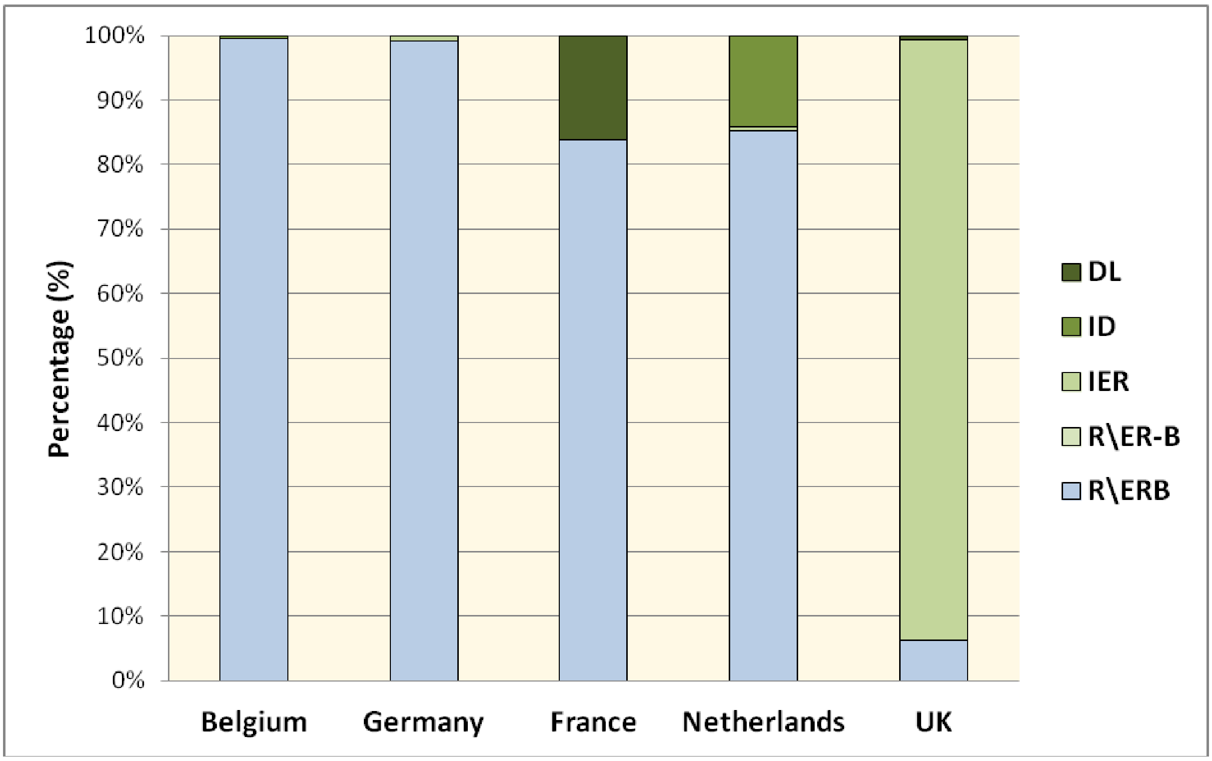

Figure 10: Treatment applied to animal wastes (manure, slurry and spoiled straw) in Belgium, Germany, France, the Netherlands and the United Kingdom in 2012 expressed in percentage. DL = Deposit onto or into Land; ID = Incineration/Disposal; IER = Incineration/Energy Recovery; R\ER-B = Backfilling; R\ERB = Recovery other than Energy Recovery, excluding Backfilling.

Source: data collected from EUROSTAT®

In Belgium and Germany, animal wastes are mainly recovered via R\ERB methods/techniques. This category includes direct recovery in agriculture but also the recovery techniques applicable to specific components such as N, P and K. In France, about 16 % of animal wastes are simply deposited into or onto land, and the remaining part is recovered in the R\ERB way. In the Netherlands most animal wastes are also recovered in agriculture (or by re-using specific components as previously described), whereas 14 % are incinerated. The UK has a completely different profile and mainly uses incineration coupled with energy recovery to treat animal wastes. About 93 % of animal wastes are incinerated to produce energy while about 6 % are used in agriculture or components recycling.

Figure 11 shows the global production of animal and vegetal wastes (considered non-hazardous) in 2012 in the European countries. Here are considered three categories:

- Animal and mixed food wastes from food preparation and products, sludges from washing and cleaning, separately collected biodegradable kitchen and canteen wastes, edible oils and fats. They originate from food preparation and production as well as separate collection.

- Vegetal wastes resulting from food preparation, sludges due to washing and cleaning, materials unsuitable for consumption and green wastes. They are generated by food and beverage production, agriculture, horticulture and forestry.
- Animal faeces, urine and manure, as described before (Eurostat, 2010).

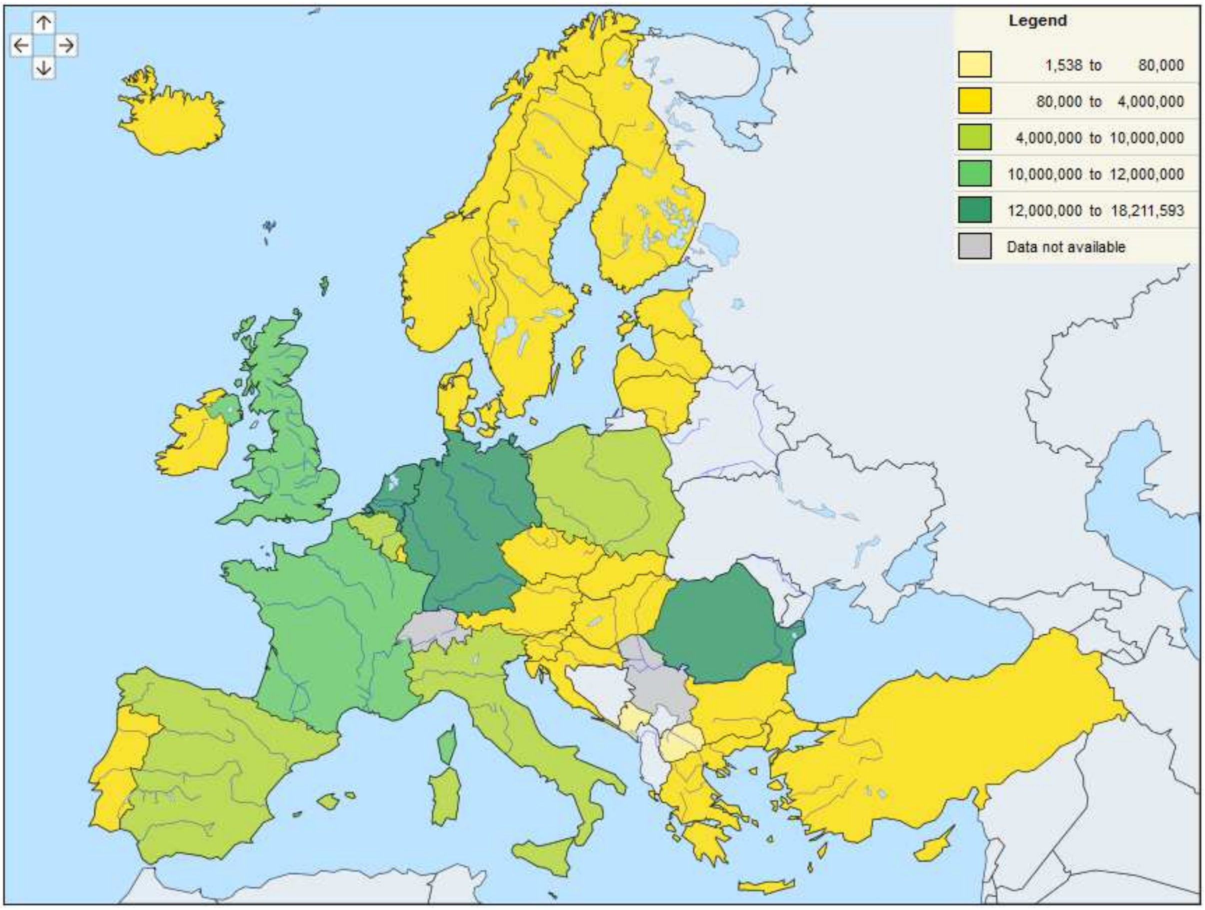

Figure 11: Total production of animal and vegetal wastes (2012) in European countries in tonnes.

Source: EUROSTAT®

5 Digestate

5.1 Composition

Digestate comes from the anaerobic biodegradation of organic wastes. Biodegradation is a microbiological process applicable to organic materials in which microorganisms degrade the matter under aerobic or anaerobic conditions (Merlin Christy et al., 2014).

Aerobic degradation of organic wastes, also called composting, transforms the organic matter into carbon dioxide, water, nitrates and sulphates. In nature, this transformation is common in forests, where droppings from trees and animals are turned into stable organic materials (Merlin Christy et al., 2014). Composting is widely applied to various types of wastes, such as green and animal wastes, giving a solid residue called compost.

Table 2 shows the composition of some samples of green waste compost. These data are only informative and were obtained from a small number of samples.

Table 2: Composition of compost obtained from green waste composting (non-exhaustive data).

Source: Bureau d'études environnement et analyses (BEAGx)

Parameter	Raw matter	Dry matter
DM (%)	45.9-77.3	
pH	6.9-8.4	
N_{tot} (%)	0.59-1.41	0.92-2
N_{NO_3} (mg N/kg)	<10-32.9	<19-42.6
N_{NH4} (mg N/kg)	<10-113	<19-220
P_2O_5 (%)	0.20-0.44	0.32-0.84
K_2O_t (%)	0.41-1.13	0.62-2.08
MgO (%)	0.31-0.92	0.58-1.38
CaO (%)	1.34-2.82	2.92-5.06
As (mg/kg)	1.06-2.4	2.3-3.3
Cd (mg/kg)	0.24-0.43	0.45-0.66
Cu (mg/kg)	11.9-36.7	24-71
Ni (mg/kg)	5.0-13.1	9.5-17
Pb (mg/kg)	18.4-54.1	40-94
Zn (mg/kg)	75.7-151.5	145-240
Hg (mg/kg)	0.028-0.07	0.06-0.11
Cr (mg/kg)	6.5-11.9	14-20
Co (mg/kg)	0.62-2.60	0.8-4.9
C (%)	8.9-14.9	12.6-27.9
C/N ratio	6.9-24.3	

Anaerobic digestion is also applicable to organic wastes. In this process, a complex mixture of microorganisms transforms organic materials into biogas. The remaining solid part, called digestate, is composed of nutrients, additional cell matter, salts and refractory organic matter. This microbiological process occurs under oxygen-free conditions. Biogas is typically composed of methane (60%), carbon dioxide (40%), water vapour and hydrogen sulphide.

Anaerobic digestion is considered to be one of the most energy-efficient and environment-friendly techniques for bioenergy production. Anaerobic treatment is widely used in various fields and devices: septic tanks, sludge digesters, industrial and municipal wastewater treatment, hazardous waste management and agricultural waste management (Merlin Christy et al., 2014).

Different types of input materials can be made re-usable by anaerobic digestion: food wastes, sewage sludge, animal wastes, green wastes, etc. Consequently, the quality of the digestate is variable and depends on the composition of these materials. These residues may contain pollutants such as heavy metals. Anaerobic digestion makes it possible to recover carbon as methane and carbon dioxide, reducing the total volume of solid input flow recovered in digestate. It also causes a concentration of the other components, such as nutrients (N and K) but also pollutants (heavy metals).

Table 3 shows the composition of some samples of digestate obtained through the anaerobic digestion of different types of organic materials, mixed or not. These data are only informative and were obtained from a small number of samples.

Table 3: Example of composition of digestate (non-exhaustive data).

Source: Bureau d'études environnement et analyses (BEAGx)

Parameter	Raw matter	Dry matter
DM (%)	3.5-5.8	
pH	8.3-9.9	
N_{tot} (%)	0.5-0.64	6.5-11.9
N_{NH4} (%)	0.19-0.39	2.3-10.9
N_{NO3} (%)	<0.001	<0.012
P_2O_5 (%)	0.044-0.26	1.24-3.0
K_2O_t (%)	0.37-0.39	4.5-4.8
As (mg/kg)	0.051-0.26	0.98-3.3
Cd (mg/kg)	0.015-0.15	0.26-1.87
Cu (mg/kg)	4.7-10.1	55-188
Ni (mg/kg)	0.42-0.93	11-13
Pb (mg/kg)	0.89-6.6	25-83
Zn (mg/kg)	21.8-27	258-771
Hg (mg/kg)	0.0015-0.0021	0.03-0.04
Cr (mg/kg)	0.7-1.3	13-23
Co (mg/kg)	0.16-0.18	3-4.4
C (%)	1.9-3.11	32-36.6
C/N ratio	3.1-3.5	

5.2 *Production and treatment*

Biogas plants accept different types of organic wastes as input materials. Biogas production is not developed equally in all European countries. **Figure 12** shows the total number of biogas plants in 2012 and 2013 in Belgium, Germany, France, the Netherlands and the UK.

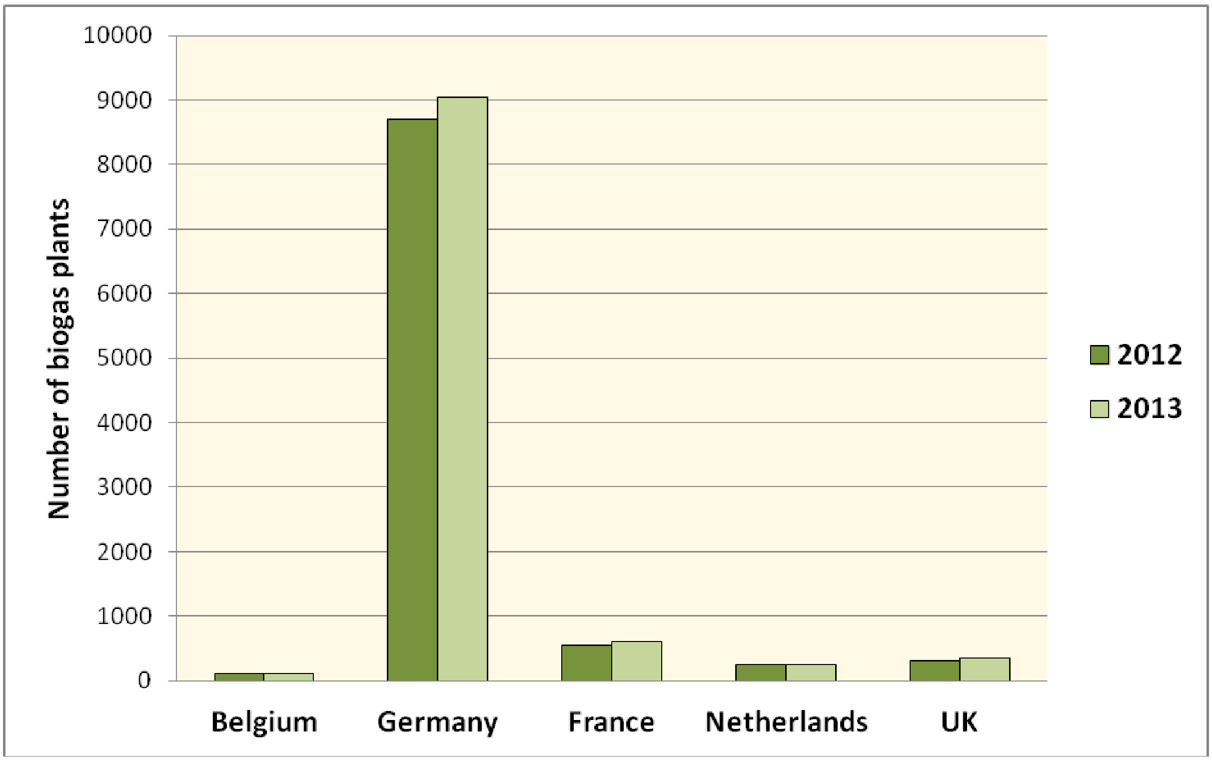

Figure 12: Total number of biogas plants in Belgium, Germany, France, the Netherlands and the UK in 2012 and 2013.

Source: European Biogas Association, (2014)

The biggest biogas producer is Germany, with a total number of biogas plants of 9,035 in 2013. The other countries had far fewer biogas plants in 2013 (118, 610, 252 and 360 plants in Belgium, France, the Netherlands and the UK). As the biggest European biogas producer, Germany also produces most of the digestate generated in Europe. The EU-28 member states, excluding Malta but including Switzerland, had 14,572 biogas plants in 2013, which means that Germany owns 62 % of all biogas plants. The two other leading biogas producers are Italy and Switzerland, with 1,391 and 620 biogas plants in 2013. However, it must be kept in mind that Germany and Italy had to abide by the new Renewable Energy Act (EEA) and slow down the development of biogas plants (European Biogas Association, 2014).

Figure 13 shows the distribution of biogas plants by sector: agriculture, sewage, landfill and others.

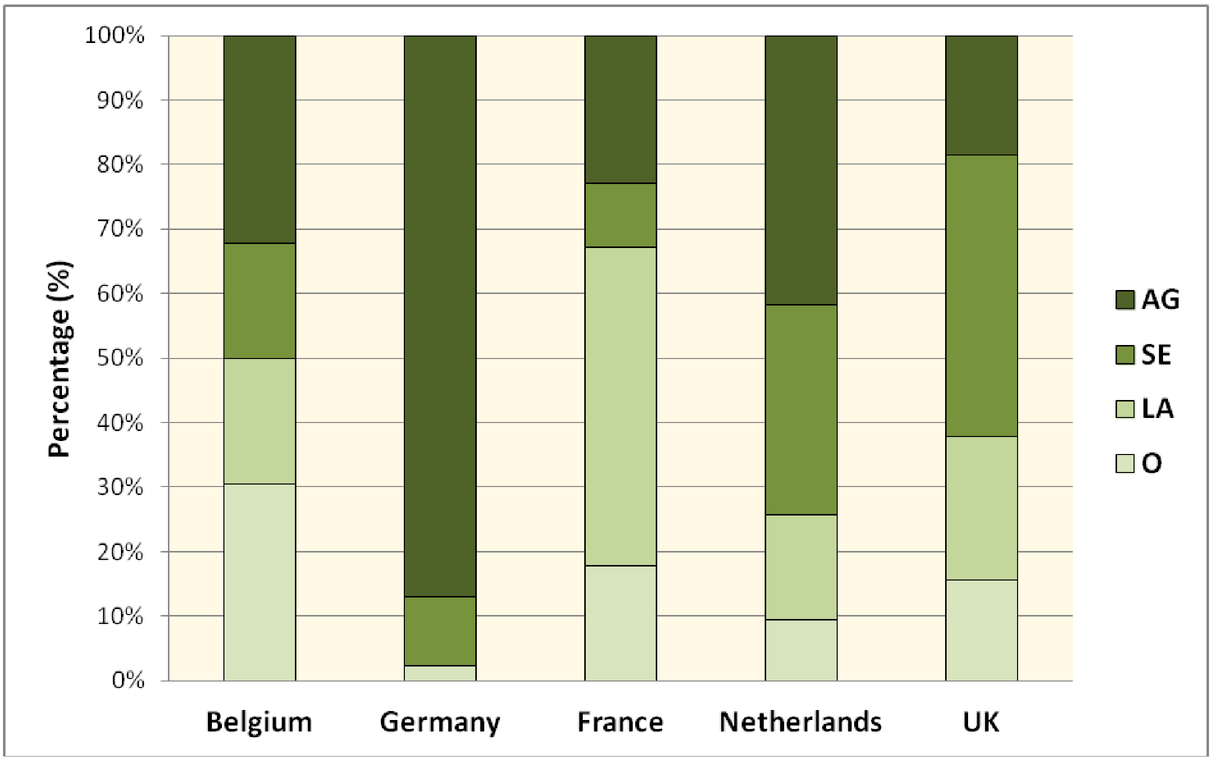

Figure 13: Distribution of biogas plants by sector in Belgium, Germany, France, the Netherlands and the UK in 2013. AG = Agriculture; SE = Sewage; LA = Landfill; O = Others.

Source: European Biogas Association, (2014)

The distribution of biogas plants by sector (agriculture, sewage, landfill and others) is quite balanced in the case of Belgium. Germany mostly sees agricultural wastes as suited to anaerobic digestion. Sewage sludge is also considered but to a lesser extent (about 11 %). In France, landfill is the leading sector (49 % of total French biogas plants), while agricultural wastes, sewage sludge and other wastes are digested in 18, 10 and 23 biogas plants. The anaerobic digestion of agricultural wastes is also very developed in the Netherlands (42 % of the plants), but this trend is linked to the high production of manure, slurry and spoiled straw (see **section 4.2.**). In the UK, sewage sludge is predominant, with 44 % of the biogas plants processing this type of waste. This is due to the high production of sewage sludge in this country (see **section 6.2.**).

The quantity of digestate produced in a European country can be seen as an indication of its probable biogas production. **Figure 14** shows the production of biogas in European countries.

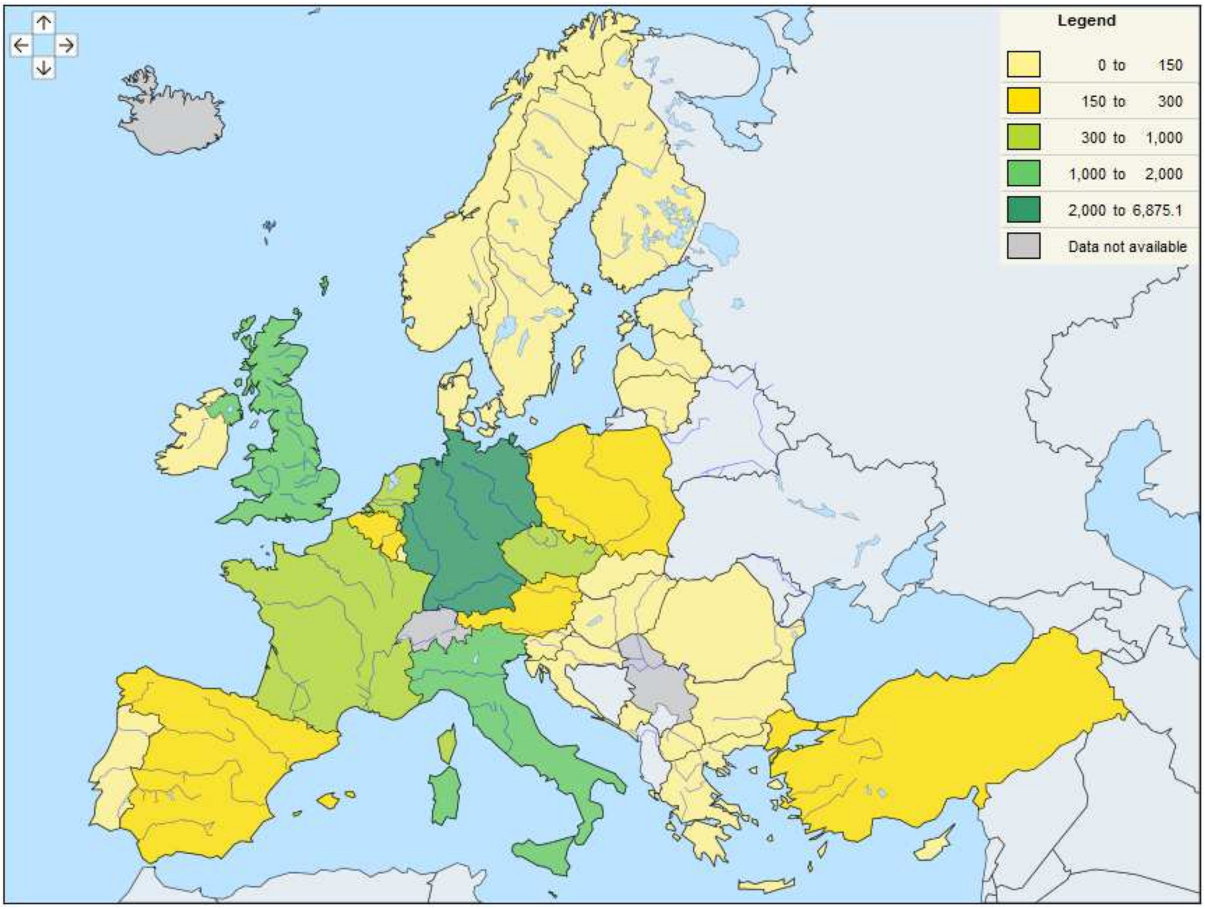

Figure 14: Total production of biogas (2013) in European countries in thousand tonnes oil equivalent.

Source: EUROSTAT®

This map highlights the highest biogas productions in Germany and Italy (data were not available for Switzerland). This is closely related to the numbers of biogas plants, estimated at 9,035 in Germany and 1,391 and Italy (European Biogas Association, 2014). However, the 2013 total production of biogas in the UK, amounting to 1.824 million tonnes oil equivalent, is certainly worth mentioning. Germany produced 6.875 million tonnes oil equivalent of biogas in 2013 and is the biggest biogas producer in Europe.

Anaerobic digestion of animal wastes (manure, slurry and spoiled straw) has been discussed in section **4.2** and belongs in the "Recovery other than Energy Recovery, excluding Backfilling" category. The treatments of sewage sludge are further discussed in section **6.2**. Here, we will focus on composting and anaerobic digestion of household wastes, as landfills are the third major sector to be considered in the field of biogas (and digestate) production. **Figure 15** shows the amounts of household wastes treated by composting or anaerobic digestion in Belgium, Germany, France, the Netherlands and the United Kingdom.

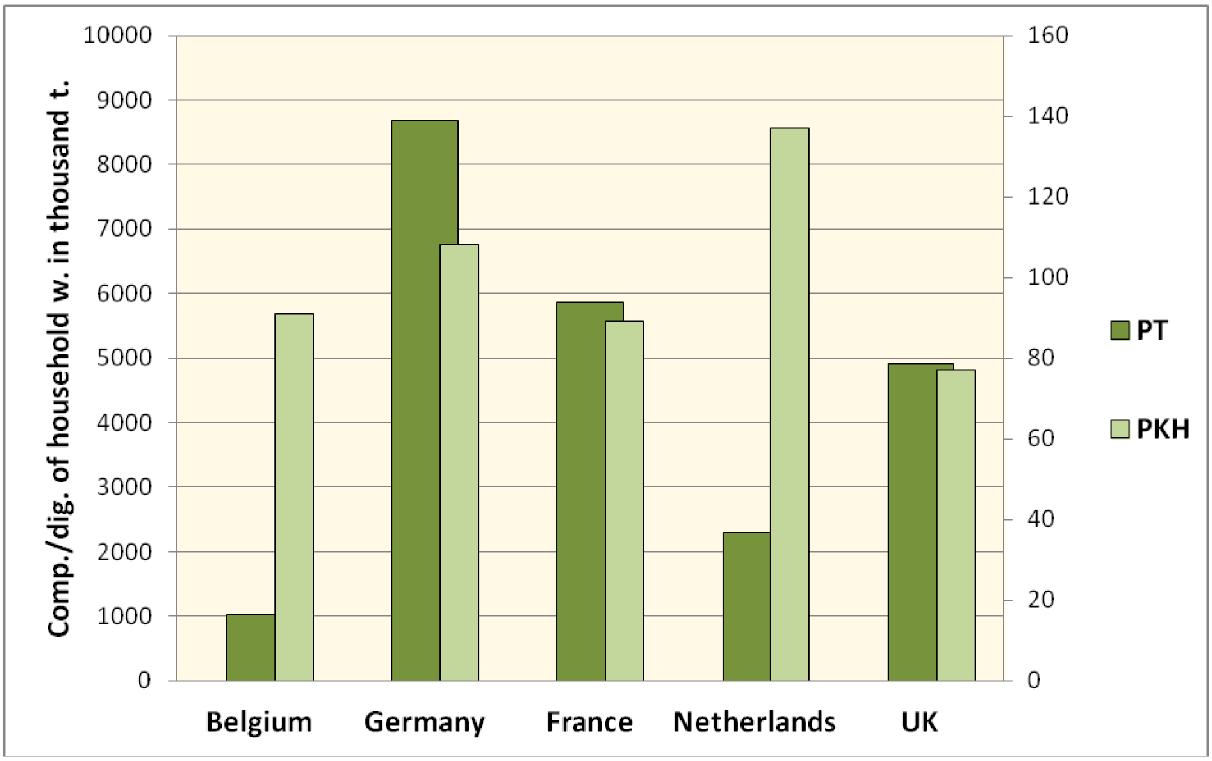

Figure 15: Amounts of household wastes treated by composting and anaerobic digestion in Belgium, Germany, France, the Netherlands and the United Kingdom in 2013 expressed in thousand tonnes (noted PT, in dark green, left scale) and in kg per capita (noted PKH, in light green, right scale).

Source: EUROSTAT®

Composting and anaerobic digestion are widely used in the five countries but it is in the Netherlands that they are comparatively the most popular. Germany comes in second though it is the biggest user of these techniques in terms of total quantities of household wastes. France, the UK, the Netherlands and Belgium used these processes to treat about 6, 5, 2 and 1 million tonnes of household wastes in 2013.

6 Sewage sludge

6.1 Composition

Sewage sludge is a semi-solid residue obtained from wastewater treatment. More specifically, the treatment of municipal wastewater leads to the production of huge amounts of sewage sludge. During the last few years, the worldwide production increased dramatically and this trend will most probably intensify in the years to come. Land application is the most common means of recovering sewage sludge because this material contains easily available nutrients. N, P, K and micro-nutrients are particularly beneficial to forestry, vegetal production and landscaping. Applying sewage sludge onto agricultural lands improves the physical, chemical and biological properties of soils (Pathak et al., 2009). However, sewage sludge also contains notable concentrations in heavy metals. The repeated application of sewage sludge onto agricultural land can therefore lead to the release and accumulation of heavy metals in the soil owing to the decomposition of the organic matter contained in the sludge. These metallic elements can contaminate soils for up to 20 years after the application of sewage sludge. A further problem is the contamination of groundwater and surface water by these heavy metals. Leaching to the groundwater can also affect the nutrients themselves if they are not absorbed by vegetables. Finally, toxic organic pollutants and pathogenic bacteria can also cause serious environmental problems (Pathak et al., 2009), which can be prevented by using the above-mentioned techniques.

Table 4 shows the composition of some samples of raw activated sludge, thickened sewage sludge and dehydrated sewage sludge (after addition of lime). These data are only informative and were obtained from a small number of samples.

Table 4: Composition of different types of sewage sludge (non-exhaustive data).

Source: Bureau d'études environnement et analyses (BEAGx)

	Activated sludge		*Thickened sewage sludge*		*Dehydrated sewage sludge*	
Parameter	**Raw matter**	**Dry matter**	**Raw matter**	**Dry matter**	**Raw matter**	**Dry matter**
DM (%)	0.4-1.05		3.5-8.8		21.5-24.9	
pH	6.7-7.6		5.8-6.4		11.9-12.3	
N_{tot} (%)	0.031-0.073	7.5-7.75	0.21-0.41	4.7-6	0.77-1.01	3.09-4.08
N_{NO3} (%)	0-0.002	0-0.5	0	0	0	0
N_{NH4} (%)	0.003-0.005	0.48-0.75	0.029-0.041	0.33-1.17	0.09-0.024	0.11-0.38
P_2O_5 (%)	0.014-0.024	2.4-3.5	0.11-0.2	2.3-3.1	0.52-0.76	2.42-3.08
K_2O_t (%)	0.005-0.008	0.67-1.25	0.03-0.08	0.86-0.91	0.08-0.15	0.32-0.61
As (mg/kg)	0.0079-0.034	1.98-3.27	0.175-0.67	5-7.63	<1.25	<5
Cd (mg/kg)	0.0034-0.0057	0.54-0.85	0.05-0.24	1.02-2.77	0.19-0.36	0.904-1.44
Cu (mg/kg)	0.58-1.09	104-145	6.01-14	128-160	21.7-23.7	95.2-101
Ni (mg/kg)	0.068-0.231	17-22	0.67-2.7	14.2-30.9	3.2-5.5	14.9-22.1
Pb (mg/kg)	0.128-0.273	26-32	1.59-7.3	34-83	10.5-38	42.3-177
Zn (mg/kg)	3.44-6.09	580-860	27.9-86.4	798-982	101-178	407-721
Hg (mg/kg)	0.00084-0.0019	0.18-0.21	0,019	0.22-0.54	0.125-0.27	0.5-1.24
Cr (mg/kg)	0.072-0.41	18-39	0.79-4.6	16.9-52.2	4.62-6.52	21.5-26.2
C (%)	0.16-0.35	33.3-38.9	0.16-0.35	33.3-38.9	4.7-7.3	19-34
C/N ratio	6.2-7.1		6.2-7.1		6.2-7.1	

6.2 Production and treatment

Urban wastewater is a major resource which must be taken into account in respect of opportunities regarding nutrient recovery. The majority of people in Belgium, Germany, France, the Netherlands and the UK are connected to a wastewater treatment system. **Figure 16** shows the population reliant on wastewater treatment in the five countries.

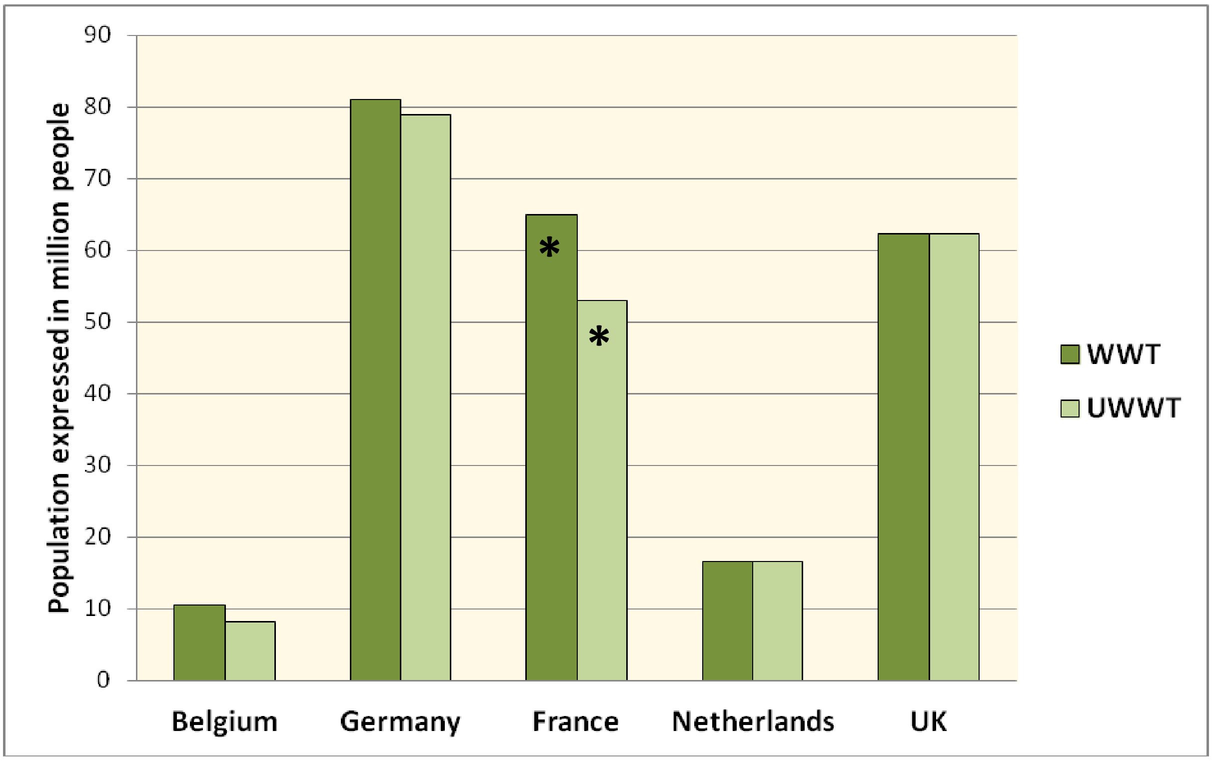

Figure 16: Population reliant on wastewater treatment in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 expressed in million people. WWT = People connected to any type of Wastewater Treatment; UWWT = People connected to Urban Wastewater Treatment Plants. * The French data relate to 2011.

Source: data collected from EUROSTAT®

Whatever the country, most people are connected to a wastewater treatment system. In most cases, people are connected to urban wastewater treatment plants (WWTPs). About 78, 97, 82, 99 and 100 % of people were connected to WWTPs in 2010 (2011 in France) in Belgium, Germany, France, the Netherlands and the UK.

Figure 17 shows the production of sewage sludge in the five countries.

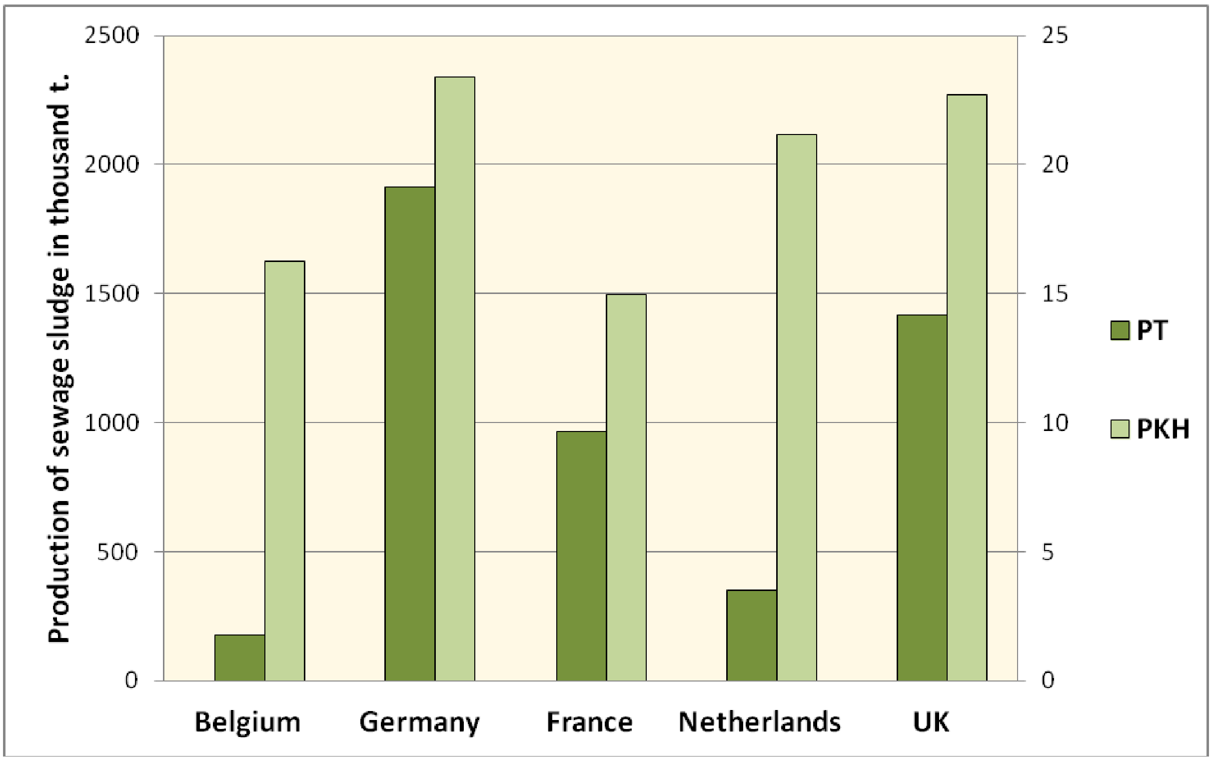

Figure 17: Total production of sewage sludge (dry matter) in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 expressed in thousand tonnes (noted PT, in dark green, left scale) and in kg per capita (noted PKH, in light green, right scale) (non-hazardous wastes).

Source: data collected from EUROSTAT®

The quantities of sewage sludge produced per capita vary from country to country. In 2010, Belgium and France registered the lowest productions with a value close to 15 kg per capita whereas Germany, the Netherlands and the UK produced more sewage sludge with levels of 23, 21 and 23 kg per capita. There is a direct correlation between the various populations and their productions of sewage sludge. This is due to a global trend of connection to WWTPs. Belgium, Germany, France, the Netherlands and the UK respectively produced 0.176, 1.911, 0.966, 0.351 and 1.419 million tonnes of sewage sludge in 2011.

Another important parameter worth considering is the treatment of sewage sludge in each country. **Figure 18** shows the different treatments applied to sewage sludge in the five countries.

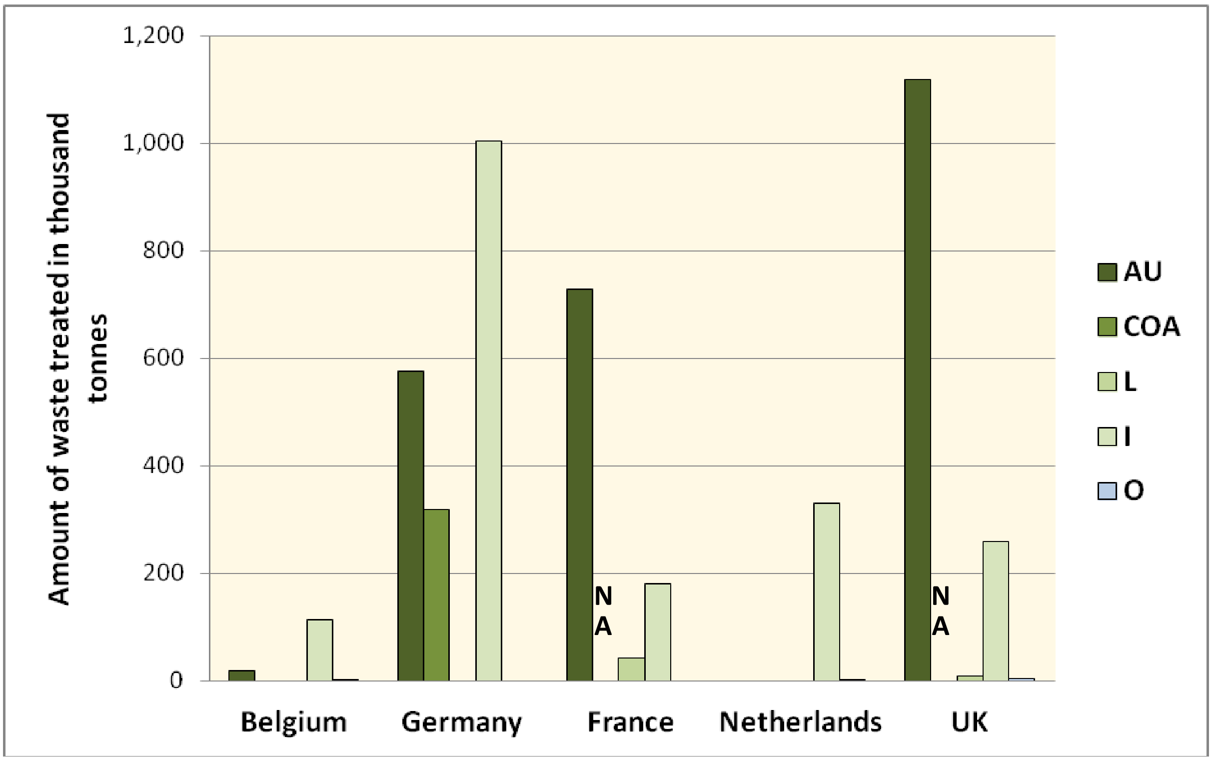

Figure 18: Treatment applied to sewage sludge in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 expressed in thousand tonnes. AU = Agricultural Use; COA = Compost and Other Applications; L = Landfilling; I = Incineration and O = Other techniques. NA = not available (data of COA relating to France and the UK).

Source: data collected from EUROSTAT®

The category "COA" relates to all sewage sludge applications after mixing with other organic material and compost production in parks, horticulture, etc. Each country shows a specific profile of sewage sludge treatment. Belgium and Germany mostly use incineration to eliminate this waste while France and the UK mainly re-use sewage sludge in agriculture. Incineration, which generates ashes, is quite common in the five countries, with quantities of 0.113, 1.004, 0.181, 0.33 and 0.26 million tonnes of sewage sludge burnt in Belgium, Germany, France, the Netherlands and the UK in 2010. Landfilling was used in France and the UK with respective amounts of 42 and 9 thousand tonnes whereas the other countries used other methods. Germany also recovered sewage sludge in agriculture (575 thousand tonnes) but also by producing compost (317 thousand tonnes). Belgium only re-used 13 % of its total production of sewage sludge in agriculture. This low percentage is due to legal constraints.

Figure 19 shows the production of common sludges in the European countries in 2012. This category includes wastewater treatment sludges coming from municipal sewerage water and organic sludges from food preparation and processing. They mainly originate from households and industrial branches with organic wastewater (mainly pulp and paper as well as food preparation and processing). They can also occur in wastewater treatment plants or in the anaerobic treatment of waste. All common sludge types are considered non-hazardous. However, it must be kept in mind that it can prove difficult to compare countries using different statistical units as they do not earmark wastes to the same economic sectors (Eurostat, 2010).

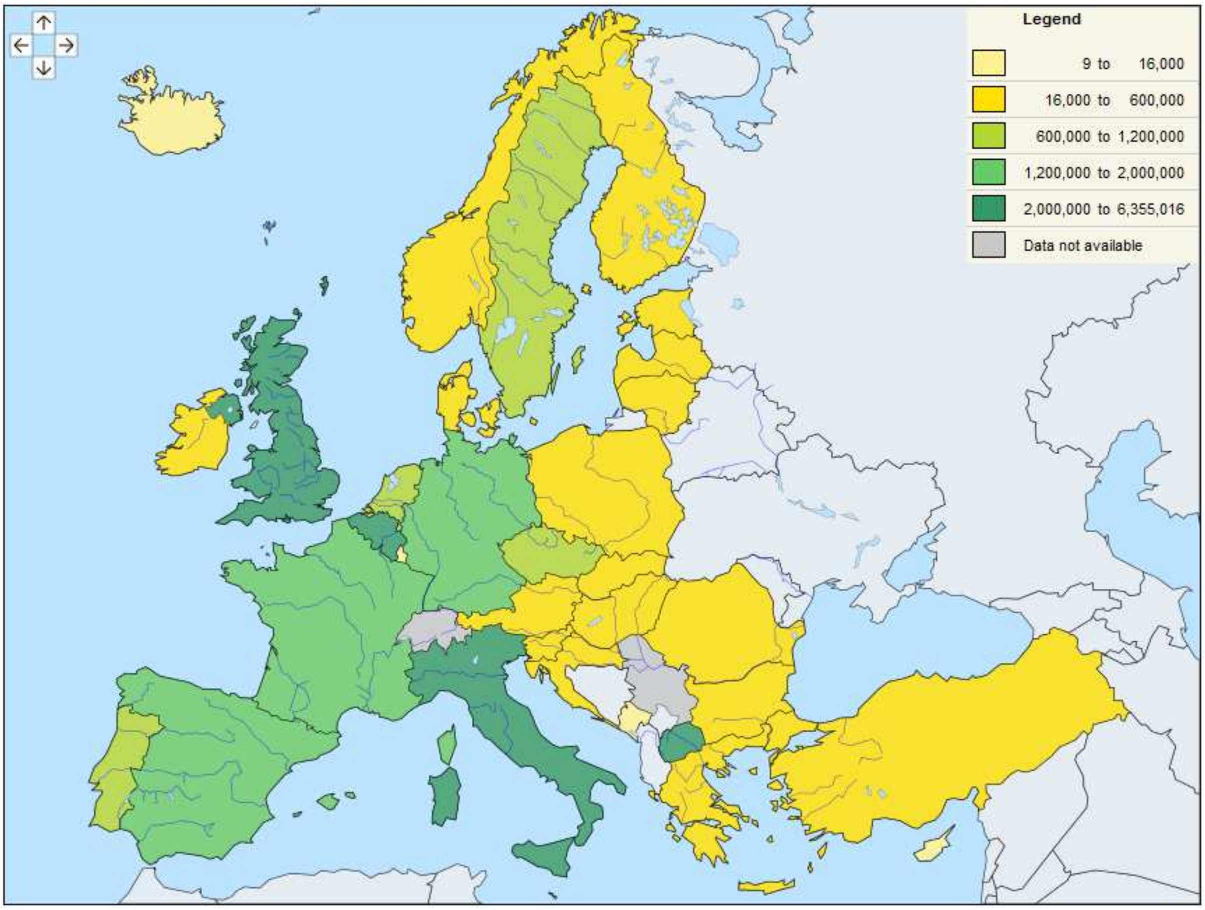

Figure 19: Total production of common sludges (2012) in European countries in tonnes.

Source: EUROSTAT®

7 Ashes

7.1 Composition

Waste incineration is commonly used in the EU-28 countries, with or without energy recovery. This process consists in the oxidation of organic materials contained in wastes causing a considerable reduction of volume. Different types of incineration exist:

- Mixed municipal waste incineration,
- Pretreated municipal or other pretreated waste incineration,

- Hazardous waste incineration,
- Sewage sludge incineration,
- Clinical waste incineration (European Commission, 2006).

Incineration leads to a loss of nitrogen. However, phosphorus and potassium are concentrated in the combustion wastes. Ashes also show high concentrations in heavy metals. Here, we will only consider two types of ashes: wood ashes and poultry manure ashes, as sewage sludge was already considered in **section 6**. Incineration leads to an increase in dry matter, phosphorus and potassium concentrations.

Table 5 shows the composition of ashes resulting from the incineration of different types of wastes: forestry chips, untreated wood, barks, wastes coming from wood industry and poultry manure. These data are only informative and were obtained from a small number of samples.

Table 5: Composition of different types of ashes (non-exhaustive data). * These data were obtained from one sample only.

Source: Bureau d'études environnement et analyses (BEAGx)

Parameter	Forestry chips	Untreated wood	Barks	Wastes from wood industry	Poultry manure
pH	12.5-12.8	10.5-12.3	11.9	11.9-12.3	13 *
N_{tot} (%)	0.07-0.12	0.09-0.38	0.03	0.08-0.13	0
P_2O_5 (%)	3.39-4.98	1.21-4.54	0.91-2.15	0.6-3.7	11.3-12.5
K_2O_t (%)	3.9-6.72	3.3-4	3.94-5.31	1.91-6.07	11.8-14.1
MgO (%)	4.17-4.2	2.89-5.6	3.96	1.25-5.66	4.5-5.6
CaO (%)	34.38-45.9	18.6-25.5	39.02	20.16-48.23	20.8-27
As (mg/kg)	2.99-6.8	44-61.5	6.6	3.16-5.2	<3 *
Cd (mg/kg)	1.3-2.7	7.5-9	2-3.8	0.2-2.06	0.8 *
Cu (mg/kg)	96.3-2796	124-994	138-175	64.6-101	350 *
Ni (mg/kg)	24-83.4	84.3-123	37.5-56.6	21.6-27.4	17 *
Pb (mg/kg)	15.95-78.6	316-680	126-152	28.7-94.6	10 *
Zn (mg/kg)	152-330	559-2332	421-745	116-168	1550 *
Hg (mg/kg)	0-0.1	0.3-0.36	0.13	0.02-0.2	<0.05 *
Cr (mg/kg)	21-1956	243-569	53.5-91.8	45.8-57.3	13 *
Mo (mg/kg)	1.1-1.4	8.4-9.2	2.8-4	0.87-1	-
C (%)	8-8.54	5.6-6.75	1.6	2.06-6.3	0
C/N ratio	67-110	42-62.6	53	26-48.8	-

7.2 Production and treatment

Incineration is a process widely used in EU countries to eliminate various types of wastes and reduce their volume. As a consequence, these countries generate considerable amounts of combustion wastes. Incineration can be considered as a thermal pre-treatment which produces secondary wastes, subsequently recovered or landfilled (Eurostat, 2010). **Figure 20** shows the production of combustion wastes in 2010 and 2012 in Belgium, Germany, France, the Netherlands and the UK. In this figure, combustion wastes are considered to be wastes from flue gas cleaning (desulphurization sludges, filter dust and cakes, fly ashes), slags, dross, skimming, boiler dusts and ashes from thermal processes. They originate from all thermal and combustion processes (power stations and other combustion plants, thermal metallurgy, casting of ferrous and non-ferrous pieces, production of glass and glass-based objects, manufacture of ceramic goods, bricks, tiles and construction products, manufacture of cement, lime and plaster). Combustion wastes are hazardous when they contain organic pollutants, oil and heavy metals (Eurostat, 2010). In **Figure 20**, only non-hazardous combustion wastes are listed.

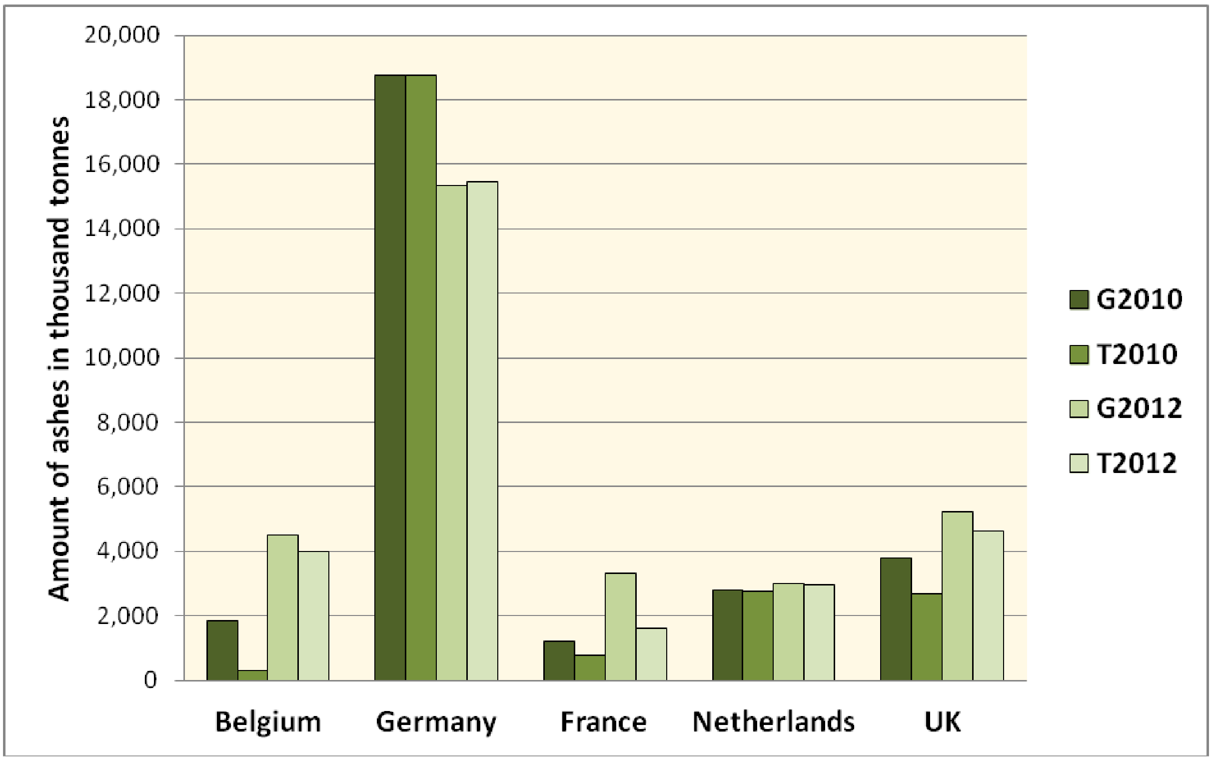

Figure 20: Production and treatment of non-hazardous combustion wastes in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 and 2012 expressed in thousand tonnes. G2010 = Amount generated in 2010; T2010 = Amount treated in 2010; G2012 = Amount generated in 2012 and T2012 = Amount treated in 2012.

Source: data collected from EUROSTAT®

Germany is the biggest producer of combustion wastes (more than 18,000 tonnes in 2010 and more than 15,000 in 2012). All those wastes were treated. The Netherlands produced approximately the same amount of combustion wastes, most of which were processed, in 2010 and 2012. Belgium showed an impressive increase of waste production from 2010 to 2012 (about 143 %), but the treatment rate also rose from 15 % in 2010 to 89 % in 2012. France was the smallest combustion waste producer in 2010 (about 1.205 million tonnes), but that production considerably increased in 2012 (about 3.320 million tonnes). Finally, the UK also showed an increase of production between 2010 and 2012 (38 %). These figures show the quantities of combustion wastes in Belgium, Germany, France, the Netherlands and the UK.

Figure 21 shows the different treatments applied to combustion wastes in the five countries.

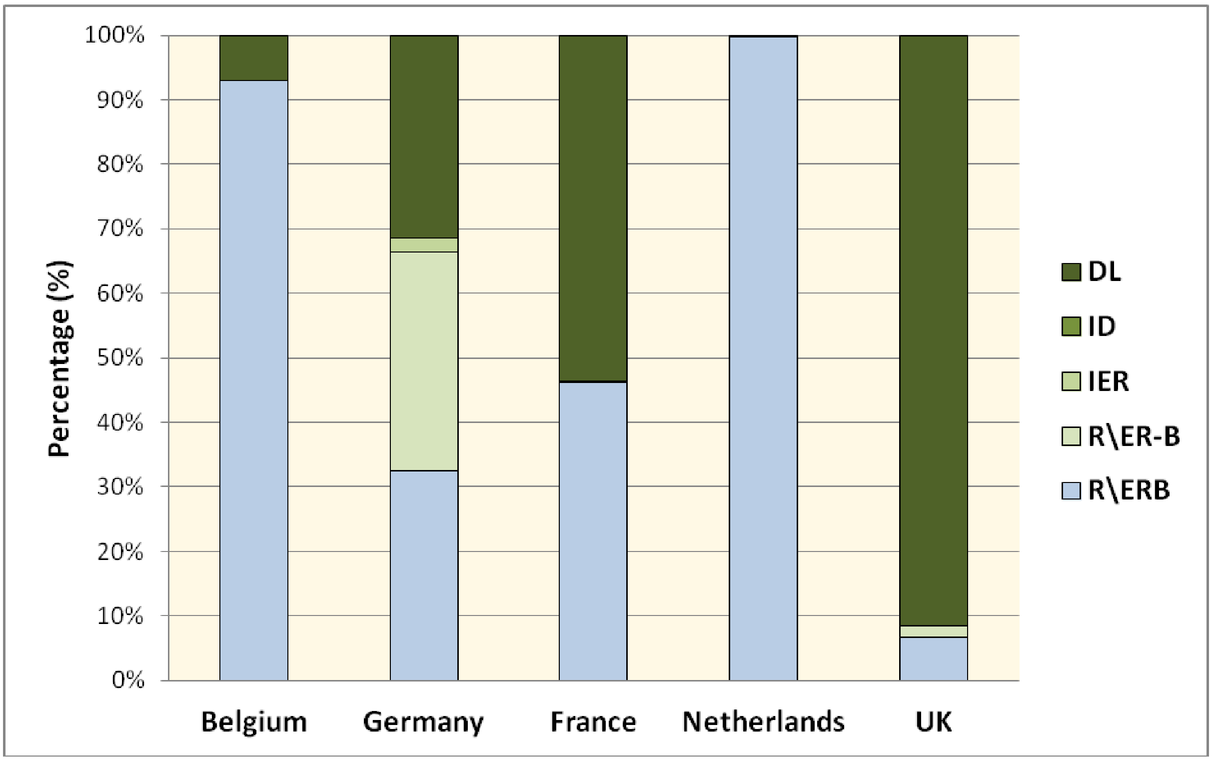

Figure 21: Treatment applied to non-hazardous combustion wastes in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 expressed in percentage. DL = Deposit onto or into Land; ID = Incineration/Disposal; IER = Incineration/Energy Recovery; R\ER-B = Backfilling; R\ERB = Recovery other than Energy Recovery, excluding Backfilling.

Source: data collected from EUROSTAT®

In Germany, about 34 % of the combustion wastes are eliminated thanks to backfilling. That country also uses simple disposal onto or into land and recovery techniques other than energy recovery, which are also very popular in Belgium (93%) and in the Netherlands (almost 100 %). In France, disposal in or on land is the main application of combustion wastes (about 54 %), whereas 46 % are processed via various recovery techniques with the exclusion of energy recovery. Disposal in or on land is also widely used in the UK (about 91 % of combustion wastes).

Combustion wastes are mainly obtained from incineration processes. In this context, some specific wastes are particularly interesting in the field of nutrient recovery. Wood wastes, for example, are definitely of interest. **Figure 22** shows the production of wood wastes in the five countries in 2010 and 2012.

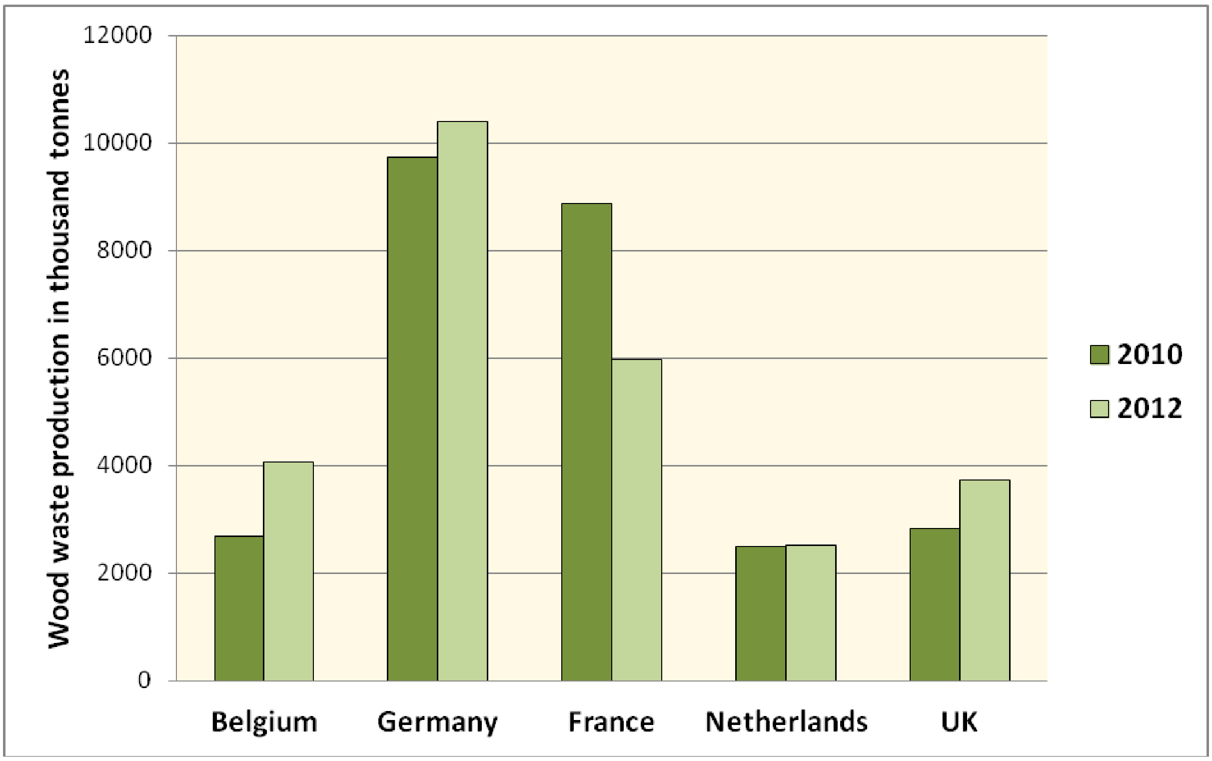

Figure 22: Production of non-hazardous wood wastes in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 and 2012 expressed in thousand tonnes.

Source: data collected from EUROSTAT®

Here, wood wastes consist of wooden packaging, sawdust, shavings, cuttings, waste bark, cork, wood from the production of pulp and paper, wood from the building industry and wood waste collected apart. They mostly originate from wood processing, the pulp and paper industry and demolished buildings but some are also available in smaller quantities thanks to wooden packaging.

Non-hazardous wood wastes are not supposed to contain hazardous substances such as mercury or tar-based protective coatings (Eurostat, 2010). It must be kept in mind that Belgium, Germany, France, the Netherlands and the UK generate relatively small quantities of hazardous wood wastes (respective productions of 0.125, 1.308, 0.088, 0.061 and 0.015 million tonnes in 2012). The biggest producers of non-hazardous wood wastes are France and Germany. The French production decreased by 49 % between 2010 and 2012. The Netherlands generated almost the same amounts of wood wastes in 2010 and 2012 (about 2.5 million tonnes). The production of wood wastes significantly increased between 2010 and 2012 in Belgium (51 %) and in the UK (32 %). A relatively low production of wood wastes was observed in the UK, considering the big population.

Figure 23 shows the different treatments applied to wood wastes in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010.

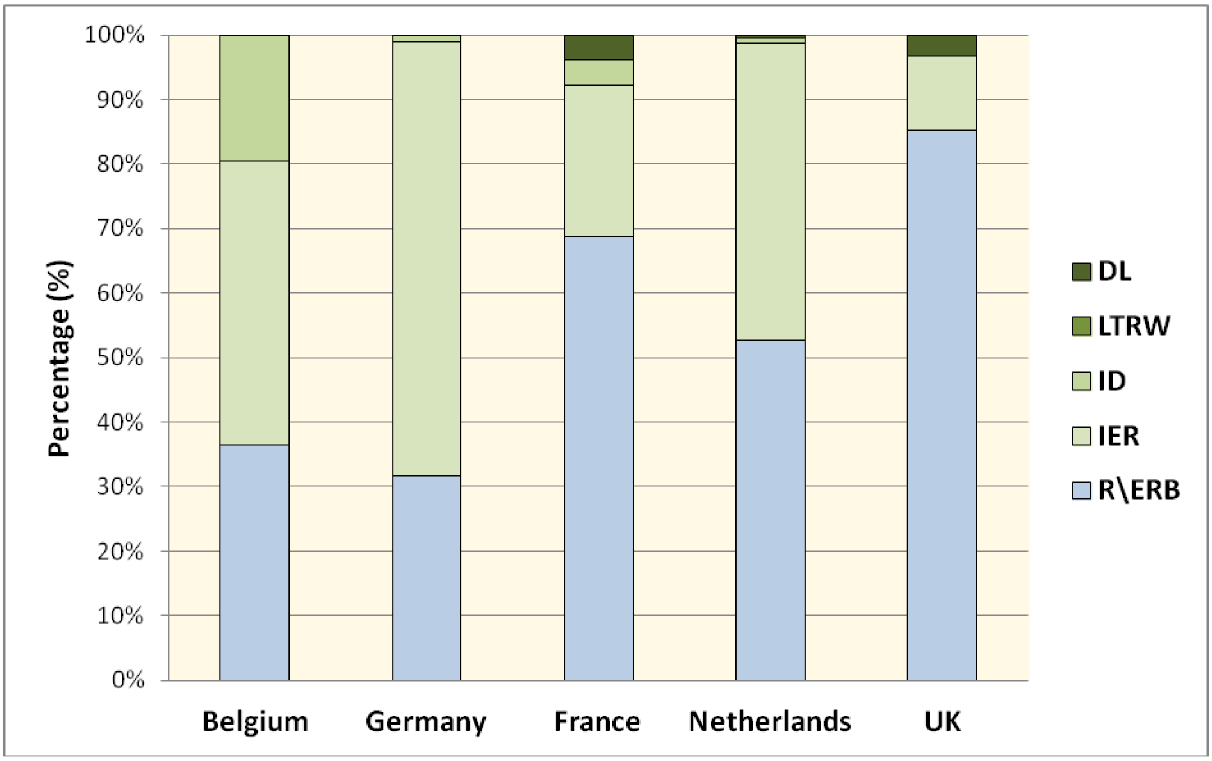

Figure 23: Treatment applied to non-hazardous wood wastes in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 expressed in percentage. DL = Deposit onto or into Land; LTRW = Land Treatment and Release into Water bodies; ID = Incineration/Disposal; IER = Incineration/Energy Recovery; R\ERB = Recovery other than Energy Recovery, excluding Backfilling.

Source: data collected from EUROSTAT®

Recovery techniques other than energy recovery are used in the five countries to process wood wastes. Incineration, with or without energy recovery, is also common in Belgium, Germany, France, the Netherlands and the UK with percentages of 64, 68, 27, 47 and 12 %. These processes generate considerable amounts of wood ashes. The other treatments are a minority.

Household wastes and sewage sludge also generate ashes owing to the incineration process. These data are presented in **sections 8.2** and **6.2**.

8 Municipal wastes

8.1 Composition

The composition of household wastes is much more difficult to establish because this group consists of many types of materials. The main categories are:

- Glass wastes,
- Paper wastes,
- Plastics,
- Metals,
- Organic materials,
- Other materials (Beigl et al., 2008).

In the context of nutrients recycling, organic materials are the most promising resources. It is hard to define a standard composition, as every single waste type has a specific concentration in N, P and K. Consequently, establishing tables of concentrations is impossible here. The complexity of household wastes aroused a real interest in establishing models to characterize the production of municipal solid wastes. In this context, Beigl et al. (2008) explained 45 different types of modelling of household wastes' production based on economic, socio-demographic or management-orientated data.

8.2 Production and treatment

Municipal wastes mainly consist of waste generated by households. They also include similar wastes coming from small businesses and public institutions. Their amounts vary from municipality to municipality and from country to country, depending on the local waste management system (Eurostat, 2015). The mean production of municipal wastes in EU-28 was 481 kg per capita in 2013, showing a progressively decrease in comparison with the productions of 503, 497 and 488 kg per capita measured in 2010, 2011 and 2012. **Figure 24** shows the total production of municipal wastes in the five countries. In Belgium, Germany, France, the Netherlands and the UK, it varied from 439 (in Belgium) to 617 kg per capita (in Germany) in 2013.

Belgium produced the smallest amount of municipal wastes (4.905 million tonnes in 2013) while Germany generated the largest quantity (49.78 million tonnes in 2013). The production of municipal wastes is inevitably proportional to the population as well.

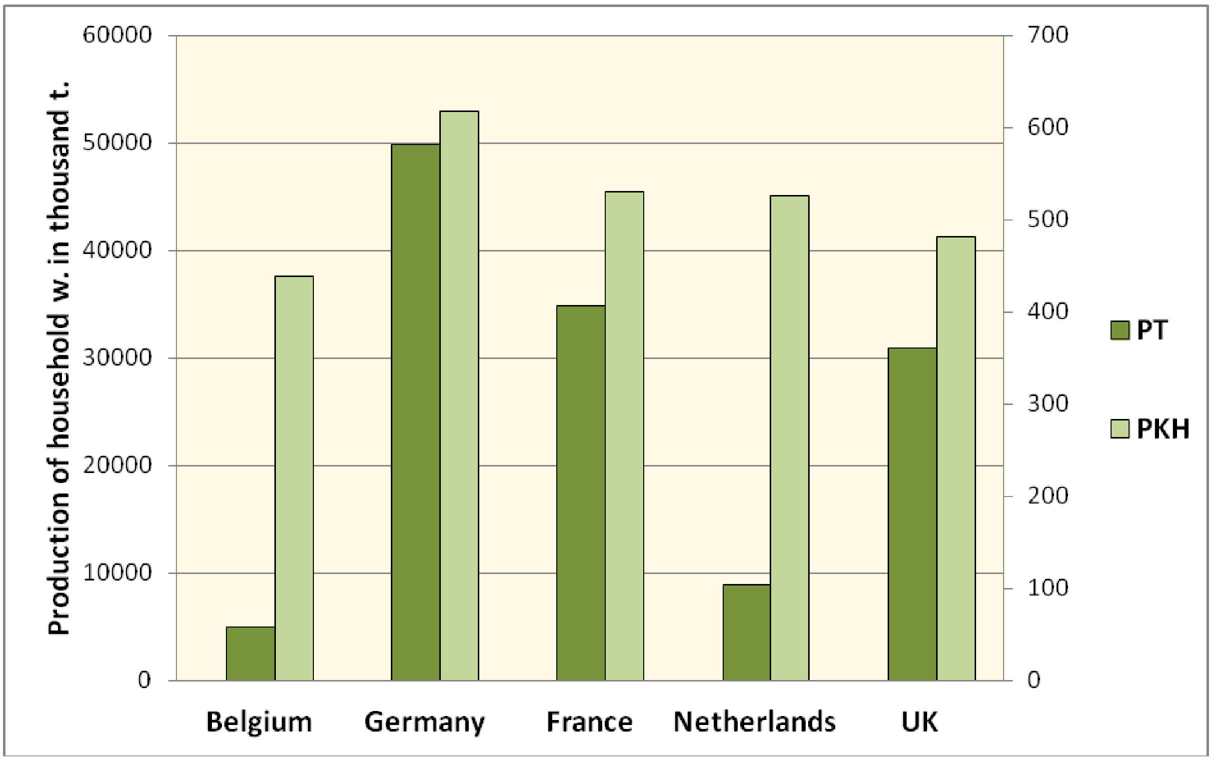

Figure 24: Total production of municipal wastes in Belgium, Germany, France, the Netherlands and the United Kingdom in 2013 expressed in thousand tonnes (noted PT, in dark green, left scale) and in kg per capita (noted PKH, in light green, right scale).

Source: data collected from EUROSTAT®

The treatment of municipal wastes also varies from country to country. **Figure 25** shows the different treatments applied to municipal wastes in Belgium, Germany, France, the Netherlands and the UK.

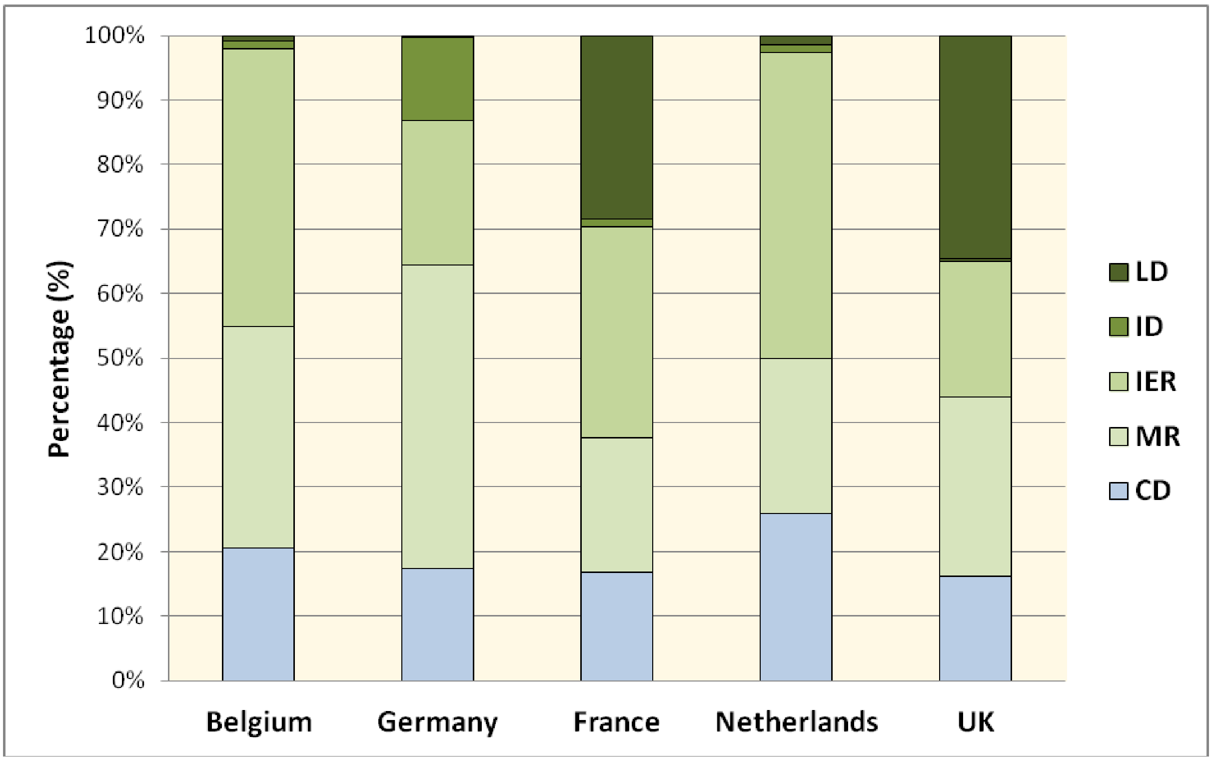

Figure 25: Treatment applied to municipal wastes in Belgium, Germany, France, the Netherlands and the United Kingdom in 2013 expressed in percentage. LD = Landfill/Disposal; ID = Incineration/Disposal; IER = Incineration/Energy Recovery; MR = Material Recycling; CD = Composting/Digestion.

Source: data collected from EUROSTAT®

In 2013, three treatment processes were common in the five countries: incineration coupled with energy recovery, material recycling and composting/digestion. It must be kept in mind that incineration (with and without energy recovery) and anaerobic digestion generate other wastes in smaller quantities. These three techniques made up 98 %, 87 %, 70 %, 97 % and 65 % of the processes municipal wastes went through in Belgium, Germany, the Netherlands and the UK. Incineration and/or disposal were quite common in Germany, still concerning about 13 % of total waste treatment. France and the UK also quite often (respectively 28% and 35%) resorted to landfilling to get rid of municipal wastes in 2013.

Figure 26 shows the evolution of recycling rates of municipal wastes in the five countries.

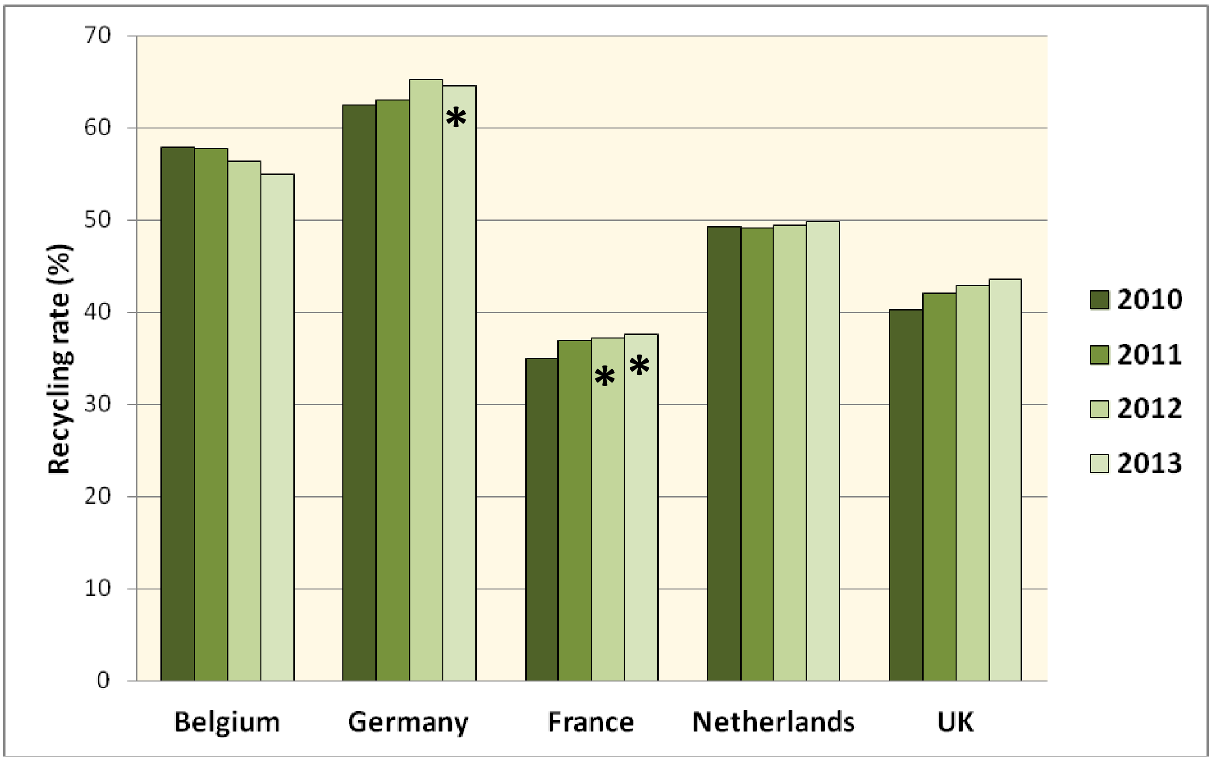

Figure 26: Recycling rate of municipal wastes in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010, 2011, 2012 and 2013 expressed in percentage. * relates to guesstimated data.

Source: data collected from EUROSTAT®

The recycling rate is the tonnage recycled from municipal waste divided by the total municipal waste. Recycling includes material recycling, composting and anaerobic digestion. For areas not covered by a municipal waste collection scheme, the amount of waste generated is estimated (Eurostat, 2015). The highest recycling rate was reached by Germany in 2012, with 65.2 % of municipal wastes recycled. The recycling processes are also developed in Belgium, with a maximal rate of 57.8 % in 2010. The Netherlands, the UK and France come in 3rd, 4th and 5th with maximal recycling rates of 49.8, 43.5 and 37.6 % in 2013.

Figure 27 shows the production of municipal wastes in EU countries.

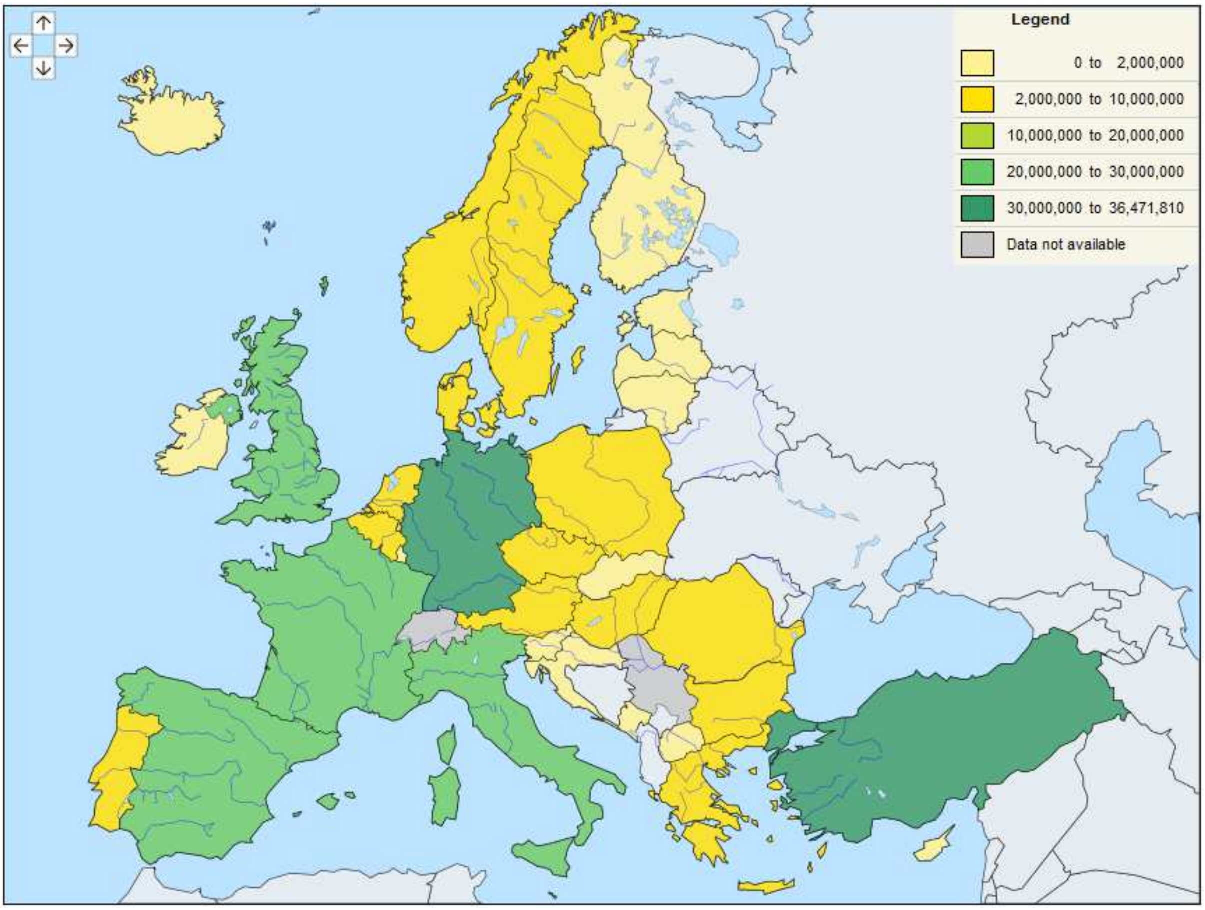

Figure 27: Total production of municipal wastes (2012) in European countries in tonnes.

Source: EUROSTAT®

Germany and Turkey were the main producers of municipal wastes in 2012, with respective amounts of about 50 and 31 million tonnes. These two countries accounted for 33 % of the total production of municipal wastes in EU-28. France, the UK, Italy and Spain generated about 14, 12, 12 and 9 % of the total production of EU-28. Belgium and the Netherlands can be seen as small producers in view of their small populations, with productions making up 2 and 4 % of the total quantity of municipal wastes in EU-28 in 2012.

9 Industrial wastes

9.1 Composition

Industrial wastes are diversified and their composition depends on the industries and activities they are generated by. Unfortunately, no relevant data are available in this connection.

9.2 Production and treatment

Figures 28 and **29** show the total production of non-hazardous wastes in Belgium, Germany, France, the Netherlands and the UK in 2012. These figures consider all economic activities (industries and other sectors, excluding municipal wastes) within EU-28:

- Agriculture, forestry and fishing,
- Mining and quarrying,
- Manufacture of food products, beverages and tobacco products,
- Manufacture of textiles, wearing apparel, leather and related products,
- Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials,
- Manufacture of paper and paper products; printing and reproduction of recorded media,
- Manufacture of coke and refined petroleum products,
- Manufacture of chemical, pharmaceutical, rubber and plastic products,
- Manufacture of other non-metallic mineral products,
- Manufacture of basic metals and fabricated metal products, except machinery and equipment,
- Manufacture of computer, electronic and optical products, electrical equipment, motor vehicles and other transport equipment,
- Manufacture of furniture; jewelry, musical instruments, toys; repair and installation of machinery and equipment,
- Electricity, gas, steam and air conditioning supply,
- Water collection, treatment and supply; sewerage; remediation activities and other waste management services,
- Waste collection, treatment and disposal activities; materials recovery,
- Construction,
- Services including wholesale of waste and scrap.

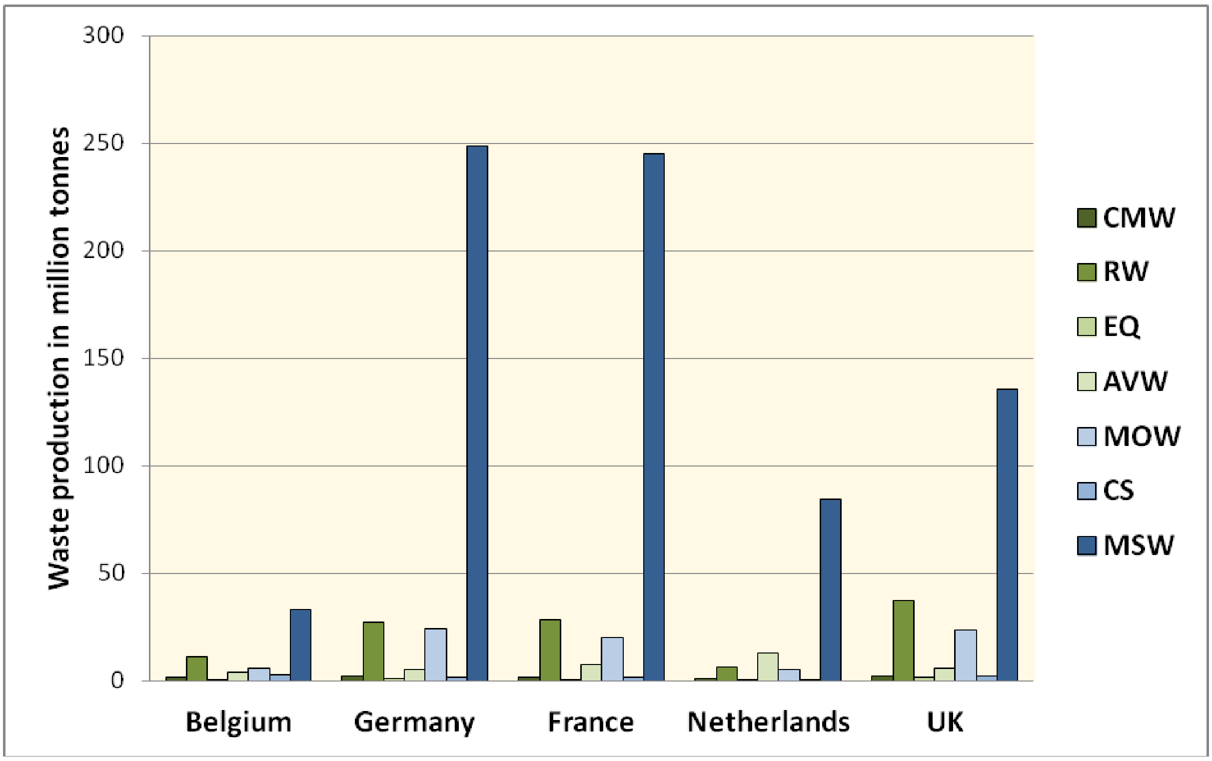

Figure 28: Waste production stemming from economic activities in Belgium, Germany, France, the Netherlands and the United Kingdom in 2012 according to the type of waste expressed in million tonnes. The following wastes are considered: Chemical and Medical Wastes (CMW), Recyclable Wastes (RW), Equipment (EQ), Animal and Vegetal wastes (AVW), Mixed Ordinary Wastes (MOW), Common Sludges (CS) and Mineral and Solidified Wastes (MSW).

Source: data collected from EUROSTAT®

The AVW, MOW and CS categories were already explained in **section 3**. The ones we wish to broach now relate to economic activities only and exclude the wastes generated by households. Chemical and medical wastes (CMW) include solid and liquid chemical catalysts; off-specification products and wastes like agro-chemicals, medicines, paint, dyestuff, pigments, varnish, inks and adhesives, including related sludges; chemical preparation waste like preservatives, brake and antifreeze fluids, waste chemicals; tars and carbonaceous waste like acid tars, bitumen, carbon anodes, tar and carbon waste; fuels, emulsions, sludges containing oil, like bilge oil, waste fuels oil, diesel, petrol, waste from oil water separators; aqueous rinsing and washing liquids, aqueous mother liquors; spent filtration and adsorbent material like activated carbon, filter cakes, ion exchangers and also medical wastes. Chemical wastes mainly originate from the chemical industry and from various industrial branches producing and using chemical products (Eurostat, 2010). They are hazardous when they contain toxic chemical compounds, oil, heavy metals or other dangerous substances, but the above figures only concern non-hazardous wastes. Recyclable wastes (RW) include various types of materials: ferrous and non-ferrous metallic wastes, glass and paper wastes, rubber wastes, plastics, wooden and textile wastes. Equipment (EQ) mainly includes electrical and electronic wastes which are quite irrelevant to nutrient recovery. Finally, mineral and solidified wastes (MSW) mainly originate from extraction and construction industries and hardly contain any nutrients.

Figure 29 shows the distribution of wastes generated by economic activities in the five countries under consideration in comparison with the mean European trend (EU-28).

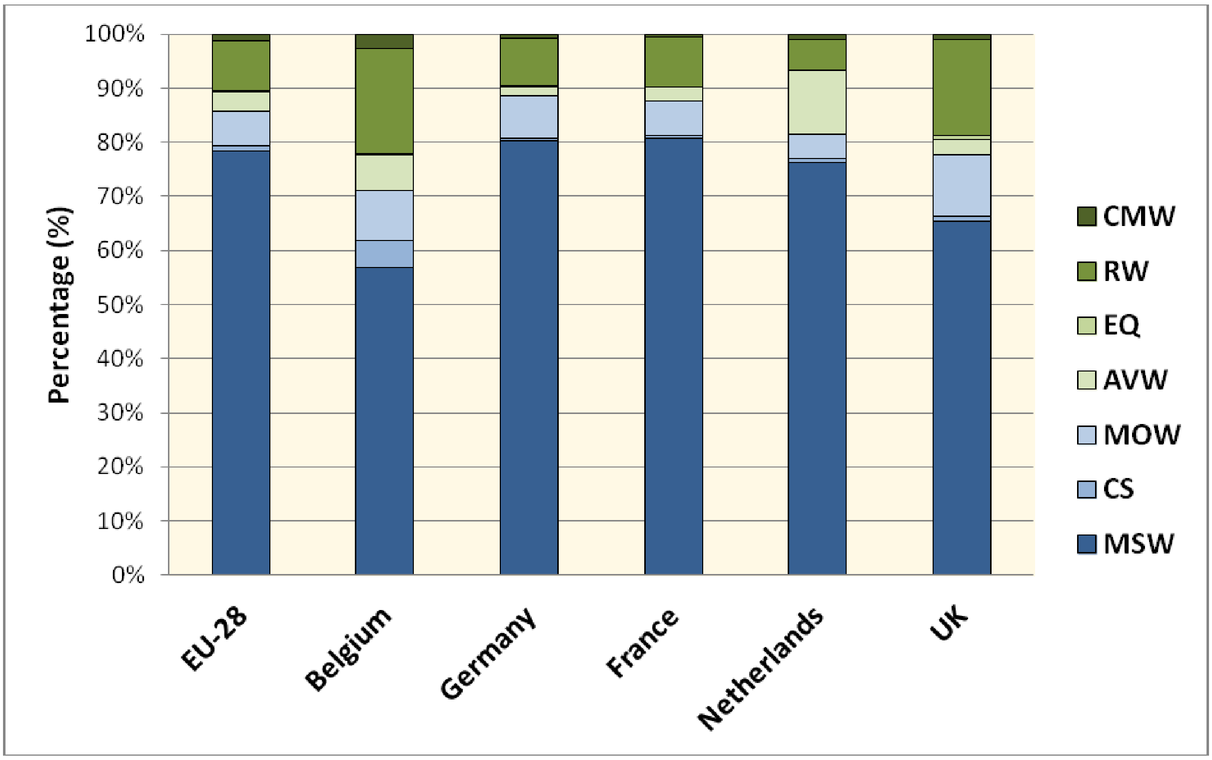

Figure 29: Distribution of waste production stemming from economic activities in Belgium, Germany, France, the Netherlands and the United Kingdom in 2012 according to the type of waste expressed in percentage. The following wastes are considered: Chemical and Medical Wastes (CMW), Recyclable Wastes (RW), Equipment (EQ), Animal and Vegetal wastes (AVW), Mixed Ordinary Wastes (MOW), Common Sludges (CS) and Mineral and Solidified Wastes (MSW).

Source: data collected from EUROSTAT®

The most promising categories are AVW, MOW and CS, coming from all types of economic activities and containing the highest concentrations in nutrients. Animal and vegetal wastes were already investigated in **section 4**. The mixed ordinary wastes presented in this section are composed of non-hazardous materials similar to household wastes but they are mainly generated by economic activities. These materials consequently contain large amounts of organic materials and can be seen as nutrient sources. **Figure 30** shows the total production of mixed ordinary wastes generated by economic activities. The figures presented in **Figure 30** relate to the category of mixed and unsorted materials, which include mixed packaging and organic wastes coming from food industries, textile industries, combustion plants, etc. (Eurostat, 2010)

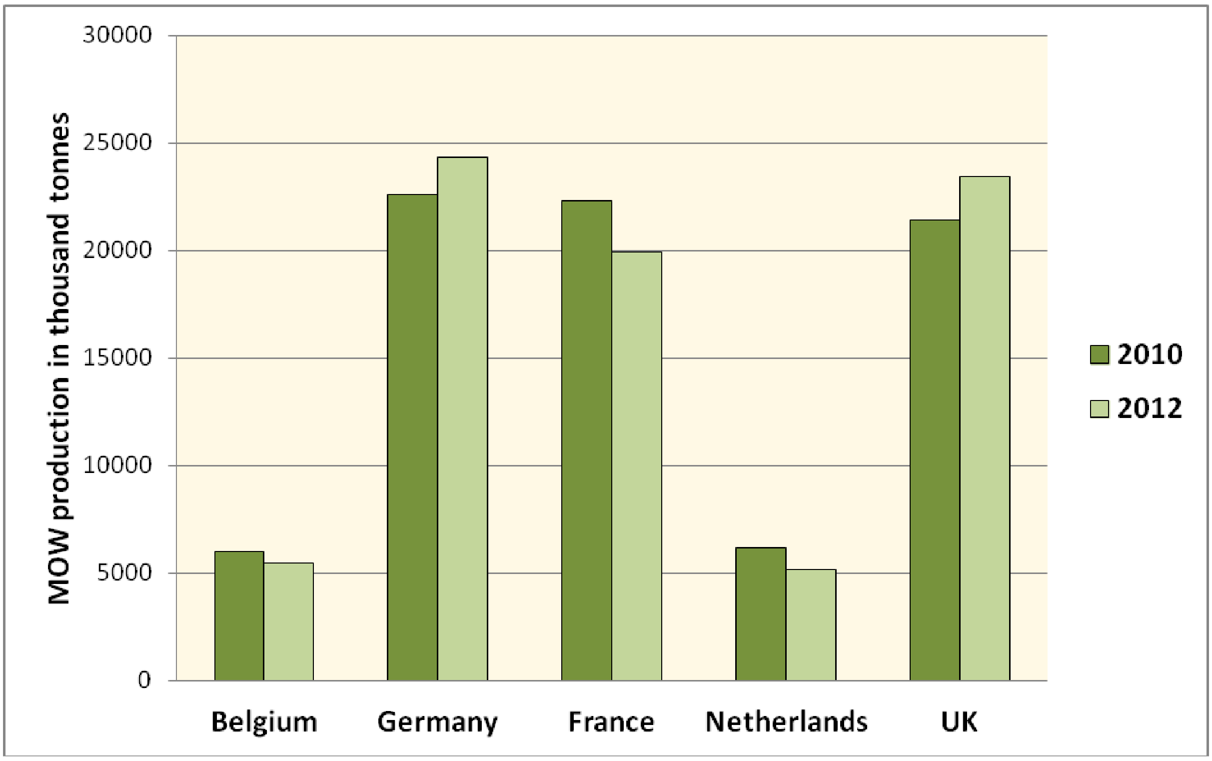

Figure 30: Production of mixed ordinary wastes mainly originating from economic activities in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 and 2012 expressed in thousand tonnes.

Source: data collected from EUROSTAT®

Germany, France and the UK generated almost the same amounts of mixed ordinary wastes in 2010 and 2012 (about 20-24 million tonnes). Belgium and the Netherlands produced far fewer wastes of that kind, with respective amounts of 5.5 and 5.2 million tonnes. These figures are comparable to the ones relating to the household wastes generated by the five countries in 2012. Belgium, Germany, France, the Netherlands and the UK generated about 5, 50, 35, 9 and 31 million tonnes of municipal wastes in 2012. Both sources can consequently be considered to be interesting nutrient stocks.

Figure 31 shows the treatments applied to the mixed ordinary wastes in 2010.

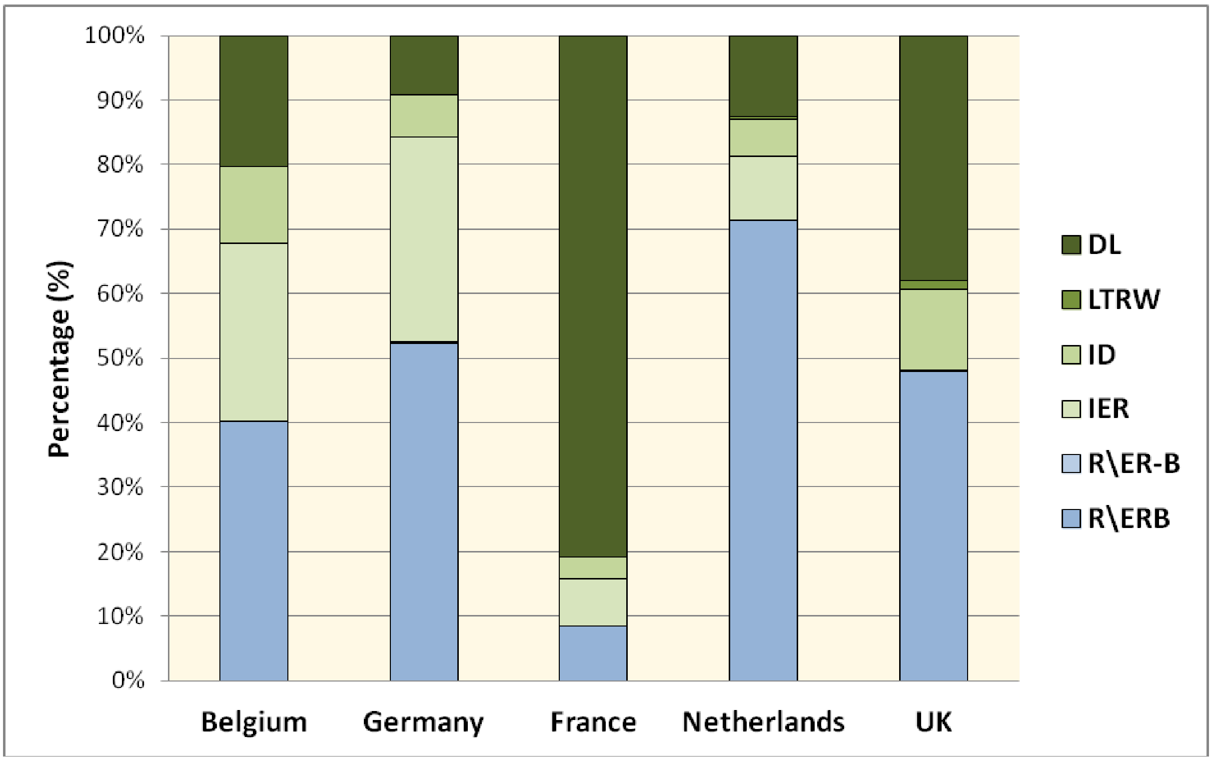

Figure 31: Treatment applied to non-hazardous mixed ordinary wastes in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 expressed in percentage. DL = Deposit onto or into Land; LTRW = Land Treatment and Release into Water bodies; ID = Incineration/Disposal; IER = Incineration/Energy Recovery; R\ER-B = Backfilling; R\ERB = Recovery other than Energy Recovery, excluding Backfilling.

Source: data collected from EUROSTAT®

It is difficult to interpret these data because of the complexity of waste composition; mixed ordinary wastes contain various materials. However, some trends can be observed. Backfilling is widely used in Belgium, Germany, the Netherlands and the UK. France uses this elimination technique with less than 10 % of MOW. However, the country spreads 80 % of these materials both into and onto the soil. Incineration is also common in the five countries, mainly in Belgium. Once again, the incineration process leads to ashes which can be recycled or sent to landfills (Eurostat, 2010).

Industrial effluent sludge is the last type of waste we will deal with. It is seen as hazardous when it contains oil and/or heavy metals and we will therefore only consider the non-hazardous sludge. Industrial effluent sludge includes sludges and solid residues from industrial wastewater treatment including external/physical treatment solid and liquid wastes from soil and groundwater remediation sludges from boiler cleaning wastes from cooling water preparation and cooling columns and mud generated by drilling. Wastewater treatment is resorted to in many industrial manufacturing sectors. Since wastewater treatment processes cannot be isolated geographically and sludges are not necessarily earmarked for primary-type activities, it is difficult to compare the countries under observation (Eurostat, 2010).

Figure 32 shows the production of industrial effluent sludge in Belgium, Germany, France, the Netherlands and the UK.

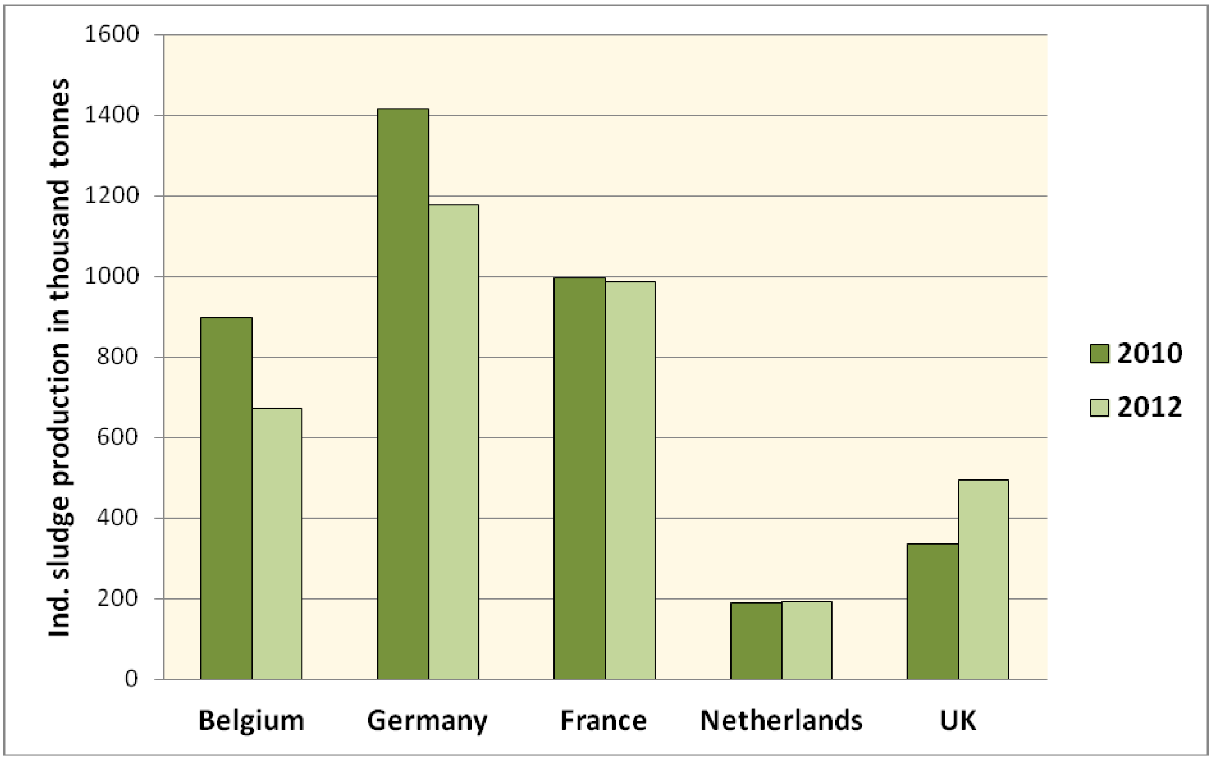

Figure 32: Production of industrial effluent sludge in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 and 2012 expressed in thousand tonnes.

Source: data collected from EUROSTAT®

The production of industrial sludge does not correlate with the local populations but depends on the industrial activities. Germany generates the highest amounts of industrial sludge while the Netherlands bring up the rear with less than 200 thousand tonnes in 2010 and 2012. The relatively high production of industrial effluent sludge in Belgium, compared with what is being observed in Germany, France and the UK, with much larger populations and areas, is worth mentioning. The industrial effluent sludge produced in the five countries is definitely worth being considered for recycling applications in the field of nutrient recovery, allowing for composition differences. Each type of industry and activity generates specific residues, but little relevant data is available.

Figure 33 shows the treatments applied to industrial effluent sludge in the five countries.

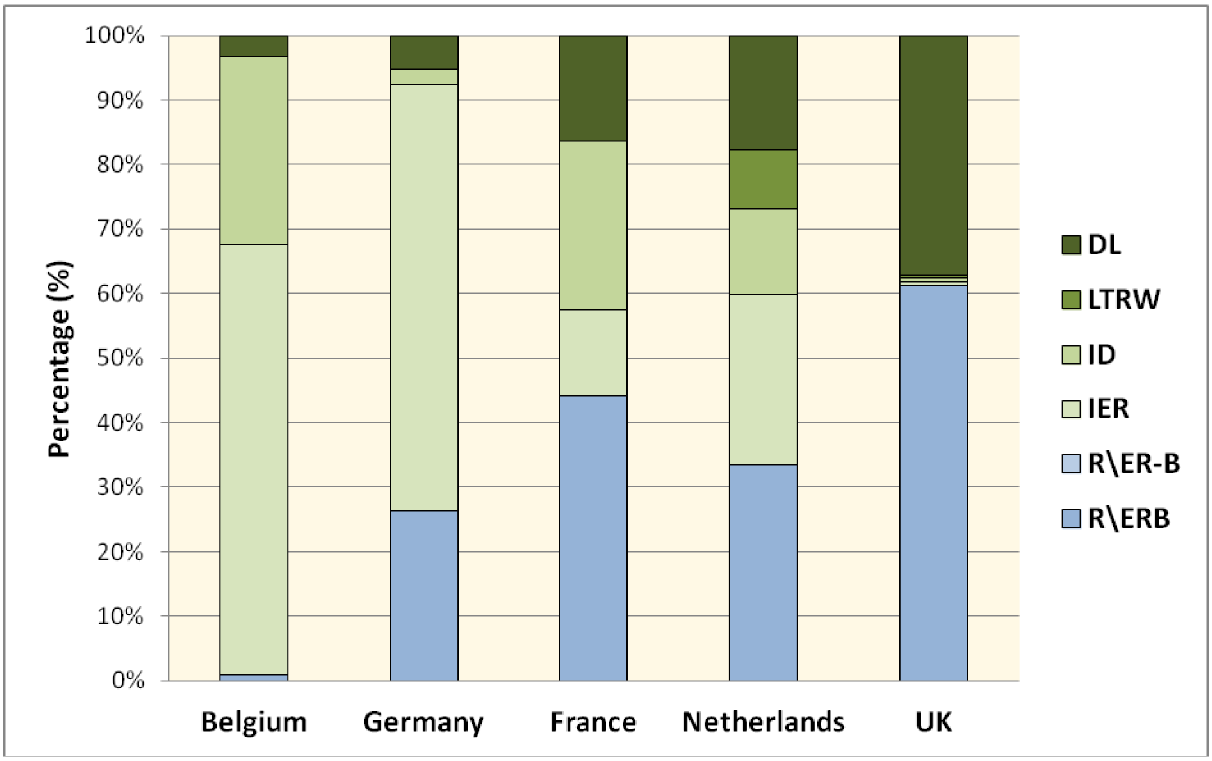

Figure 33: Treatment applied to non-hazardous industrial effluent sludge in Belgium, Germany, France, the Netherlands and the United Kingdom in 2010 expressed in percentage. DL = Deposit onto or into Land; LTRW = Land Treatment and Release into Water bodies; ID = Incineration/Disposal; IER = Incineration/Energy Recovery; R\ER-B = Backfilling; R\ERB = Recovery other than Energy Recovery, excluding Backfilling.

Source: data collected from EUROSTAT®

Incineration (with or without energy recovery) and landfilling are widely used in Belgium (applicable to about 95 % of industrial sludge). Germany also uses incineration processes with 68 % of the total production of industrial sludge. Backfilling is widely used with respective amounts of 26, 44, 33 and 61 % eliminated in Germany, France, the Netherlands and the UK. However, this process is mostly applicable to inert wastes.

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