GR3

GRASS
TO GREEN GAS

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http://www.grassgreenresource.eu/

Executive Summary

The GR3 project promotes the use of grass and other herbaceous residues from landscape management as a sustainable feedstock in biogas plants in the partner countries Belgium, Italy, Germany, Denmark and Portugal. The energy potential of these residues remains underutilized across Europe. Barriers are insufficient awareness and acceptance of suitable technologies for the mowing, storage and anaerobic digestion of grass residues, absence or lack of cooperation between stakeholders along the value chain, as well as legal barriers.

The project aimed for an increase of the renewable energy production without competing with food production, increasing the ecological landscape management as well as protect permanent grasslands from land use changes. Therefore value chains for grass residues were analysed and evaluated to increase their market uptake as biogas feedstock. The project encouraged the knowledge transfer between different actors along the potential value chains on a regional nd national level. Furthermore grass producers as municpalities, road authorities, conservancies were brought together with biogas producer. Tools and technical, economic as well as legal advice were delivered in order to trigger investments in the establishment of supply chains.

Project Introduction

Welcome to our brochure in which we can proudly present the results of the GR3-project. We will take you through all the aspects that go along with the valorisation of grass, ranging from technical to legal aspects, and from environmental to economic aspects. But first of all, a small introduction to what the GR3 project actually is about.

In short: the aim of the project is to stimulate the production of renewable energy from grass clippings through digestion. Nowadays a great amount of grass is not (optimal) valorised. When lucky, the grass clippings get composted and serve as a fertilizer, but in the majority of the cases, the grass is left on site where its decay causes emissions of greenhouse gases and other negative impact on the environment.
Unfortunately the road to get to the grass to be valorised in a digester is far from easy. This is due to several obstacles along the valorisation chain: the required logistics are complicated and missing in most of the cases, the legal framework is complex and (last but not least) there is no contact between grass clippings suppliers and (potential) consumers. In the GR3 project we have tried to tackle all these obstacles in order to support the digestion of grass throughout the different participating regions.

Of course, for this kind of job it is important to have different partners involved that all can have a local impact in their own region. As the number of regions where the project was actively implemented is limited (Flanders (B), Saarland (D), Denmark, Portugal and Veneto Region (I)) we have experienced also interest from beyond these regions (e.g. the Netherlands).
Please note that this brochure is only an overview of the output we have created. For more information on the project, the results, the partners, the case-studies, the reports, etc. please visit the project's website:
www.grassgreenresource.eu.

Determination of biogas potential from grass residues

The main objective of the inventory is to map the availability of different grass residue flows within the participating regions, as well as to catalogue the biomass quality of different categories of residues. This allows the identification of the most productive locations for grass residues fit for biogas valorisation.
The methodology to map the availability of grass residues is described in a guideline document by PXL. This document is based on the Flemish situation and explains which stakeholders can be contacted and which data have to be collected from the stakeholders, if possible. Important stakeholders are airports, municipalities and road, nature and water management organisations. Parameters that have been taken into account are area, biomass, grassland type (intensive/extensive), moisture content, biogas potential, current way of disposal, etc. Fall-back alternatives to retrieve realistic estimates were described as well.

Inventorying of grass residue flows

An inventory of the stakeholders (grass residue holders) within the different regions has been made. The management of the green space in the partner regions differs largely. Because of different management styles, it was in some regions difficult to collect detailed data on grass residue amounts. In every partner region a comprehensive inventory of the available grass residues on municipal level has been made. Besides the regional inventory a less detailed estimation of the available grass residue on national level has been carried out. The results of both inventories are shown in Table 1 and the maps illustrate the results of the regional inventory (Figure 3-Figure 7).

Table 1. Grass residue availability in the five partner regions.

Partner region/country	Amount of grass residue in ton (t) dry matter (dm) per partner region	Amount of grass residue in ton (t) dry matter (dm) per country
Denmark	500,000	500,000
Flanders (Belgium)	59,400	112,900
Saarland (Germany)	21,400	2.975,000
Lisbon (Portugal)	14,300	441,000
Veneto (Italy)	198,000	3.267,500

Catalogues of biomass quality description for different categories of grass residues

Grass is a valuable material for energy production, but the biogas potential (BGP) of grass varies greatly. To determine the biogas potential of grass, parameters such as grassland type, cutting period and storage have to be taken into account. On the other hand, grass species only have minor effects on the BGP. Based on literature survey grasslands can be divided into two types; intensive grasslands with high BGP's (between 400 and 600 Nm^3/t dm) and extensive grasslands with lower biogas potentials, which range between 100 and 250 Nm^3/t dm. Also the period of mowing (Figure 2) and the way grass is stored has a great impact on its biogas potential, each parameter can reduce the BGP by 50 %. Based on these parameters a model has been created (Figure 1), which can be used to estimate the BGP of certain grass residue flows. Figure 2 shows the effect of the mowing date on the BGP of grass, grass mown in springtime has a higher BGP than grass mown during Winter.

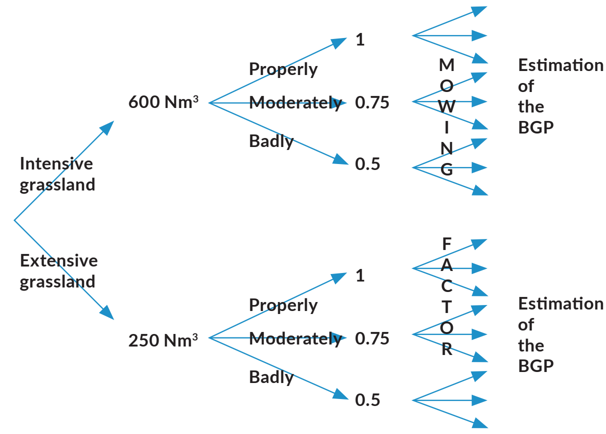


Figure 1 Model for estimation of BGP of grass

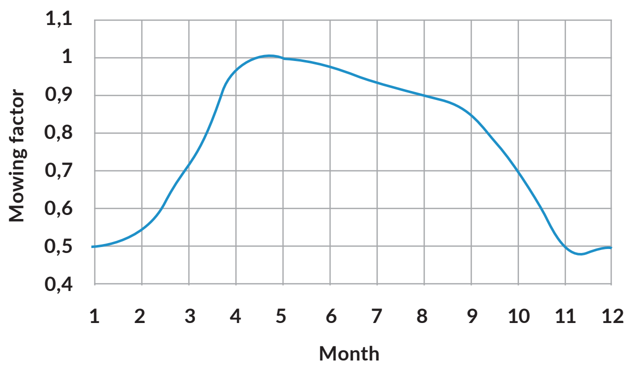


Figure 2 Effect of mowing on BGP of grass

Identification of most productive location and local stakeholders

After the inventory, the most productive locations within the partner regions have been identified based on the maps, created during the regional inventory. In each region, municipalities or clusters of municipalities that produce the large amount of grass residues have been selected (Table 2).

Table 2. Most productive locations in the Flanders, Saarland, Denmark, Veneto and Lisbon.

Flanders

Cluster	Municipality	t DM/y
1	Gent	560
	Destelbergen	442
2	Antwerpen	1,091
	Brasschaat	1,564
	Mortsel	564
	Wommelgem	496
	Schilde	1,096
	Malle	537
3	Steenokkerzeel	680
	Zaventem	2,043
4	Tienen	501
	Landen	466
	Gingelom	565
	Sint-Truiden	406
	Tongeren	384

Denmark

Cluster	Municipality	t DM/y
	Municipality	
1	Tårnby	22,228
	København	19,747
2	Varde	44,196

Lison

Cluster	Municipality	t DM/y
	Lisboa	9,464
	Oeiras	1,362
	Cascais	1,238
	Amadora	988
	Sintra	796
	Odivelas	458

Saarland

Cluster	Municipality	t DM/y
1	Bexbach	900
	Eppelborn	866
	Illingen	833
	Schiffweiler	897
	Neunkirchen	1,598
	Homburg	798
	Ottweiler	688
2	Saarbrücken	2,225

Veneto

Cluster	Municipality	t DM/y
1	Mel	3,098
	Belluno	3,086
	Farra d'Alpago	3,613
	Trichiana	1,955
2	Asiago	2,132
	Roana	2,003
3	Verona	
	Grezzana	
4	Venezia	2,089
	Chioggia	1,325
	Rosolina	1,815

Stakeholders that can be linked to the most productive locations are mainly municipalities and road, water and landscape management organisations. In some specific cases harbours and airports are important stakeholders within municipalities.

Ton dry matter by municipality in Denmark

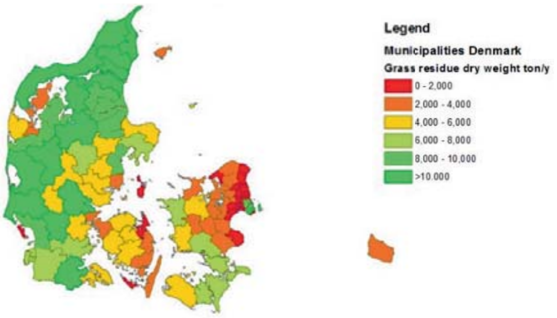


Figure 3. Grass residue availability by municipality in Denmark

Ton dry matter by municipality in Flanders

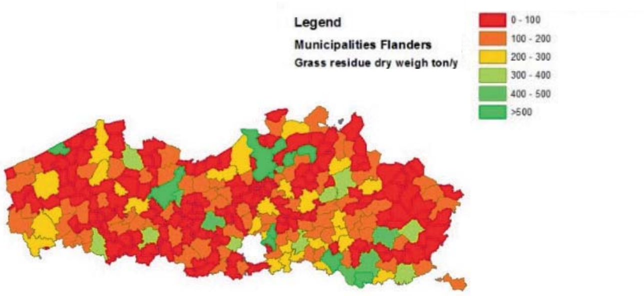


Figure 4. Grass residue availability by municipality in Flanders

Ton dry matter by municipality in Saarland

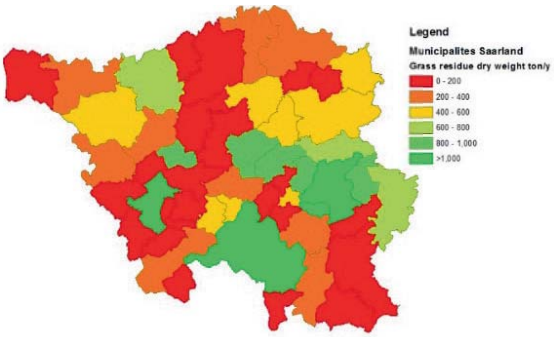


Figure 5. Grass residue availability by municipality in Saarland

Ton dry matter by municipality in Lisbon

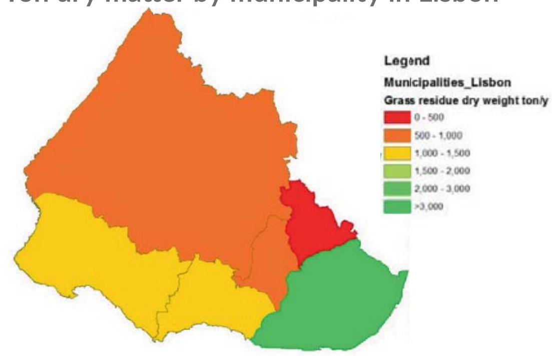


Figure 6. Grass residue availability by municipality in Lisbon

Ton dry matter by municipality in Veneto

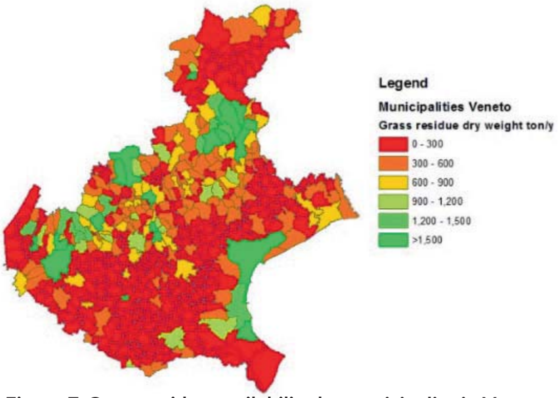


Figure 7. Grass residue availability by municipality in Veneto.

Conclusions

Through the inventory the availability of grass residues within the partner regions, Flanders, Saarland, Denmark, Veneto and Lisbon, have been determined. Based on the inventory, contacting stakeholders can be contacted and the biogas potential can be calculated for each municipality. The data can be used for matchmaking between “grass producers” and biogas plants, with the ultimate aim of converting residual grass into biogas.

Co-funded by the Intelligent Energy Europe Programme of the European Union

Best available technologies and best practices for grass residue collection and valorisation into biogas

Indentification of state-of-the-art techniques and practices

The technical aspects of grass digestion are compiled in a publically available report called “BATs and best practices for grass residue collection and valorisation”. Within this report all different stages within the valorisation train – from collection (harvesting) to digestion (biogas production) – are discussed. This way different stakeholders can learn about the do’s and don’ts within the process chain to assure that the required feedstock quality requirements at the inlet of the digester are met.
The document incorporates technical and scientific skills and helps operators and stakeholders to obtain useful data and information about collection/harvesting methods, storage, purification and digestion technologies, outlining the State Of The Art for the collection and utilization of grass residue to produce in a sustainable way the highest methane per unit area.
A special emphasis is placed on the feedstock quality requirements and all technologies available along biogas value chain to reach it. An overview on different types of digesters based on parameters such as organic loading rate, the hydraulic residence time, the biogas production and the solid content is given, with a clear distinction between a one-stage or two-stage digesters (Figure 8), and between a wet or dry anaerobic digesters. The type of feedstock is also an important parameter to choose and design a reactor type.

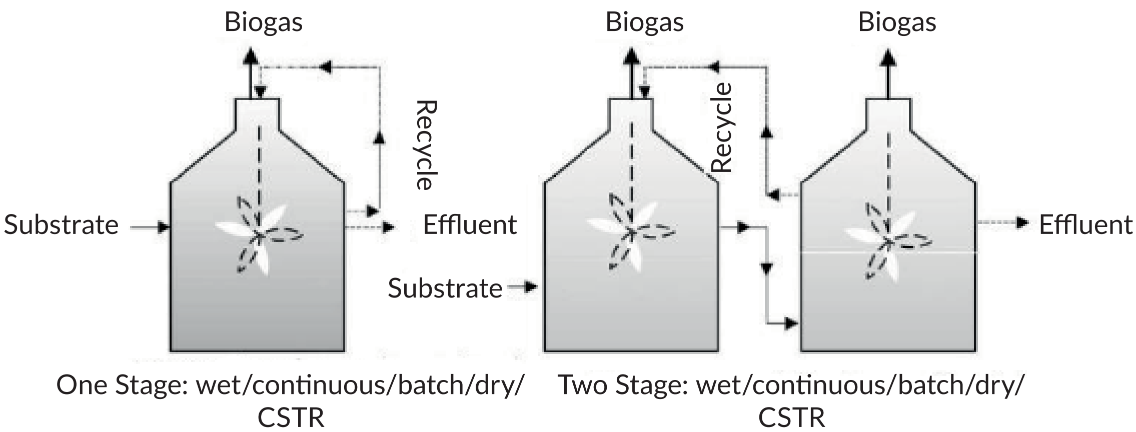


Figure 8: One-stage and two-stage CSTR (Nizamia et al., 2009)[1]

1 References: Nizamia, S.A.,Korres, N.E., Murphy, J.D. (2009). Review of the Integrated Process for the Production of Grass Biomethane. Environ. Sci. Technol. (22): 8496–8508.

Grass is an interesting material for renewable bioenergy production because it is widely available, can be collected easily and can be used immediately or after silage. On the other hand it presents some difficulties in management, before and inside the reactors. Some organic compounds digest better than others do. The bacteria in an anaerobic digester, for example, more easily consume simple sugars, than structural carbohydrates like starch or cellulose. This means that biomass which contains a lot of these easy-consumable compounds, is digested faster and/or gives a higher methane yield, while biomass-streams with a relative high percentage of fibers or other structural carbohydrates digest slower with a lower yield and often produce undesired byproducts which inhibit methane production. Poor digestibility of grassy residues is mostly due to the chemical presence of the lignocelluloses complex.

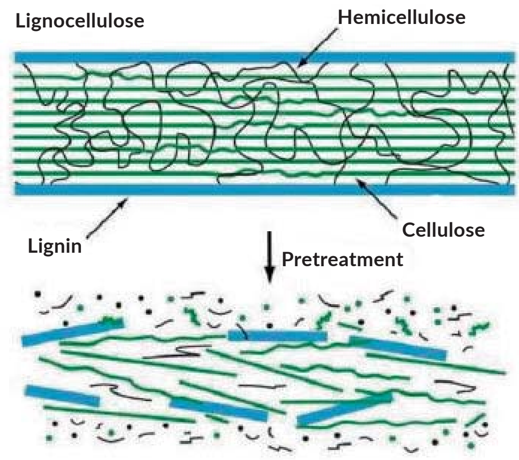


Figure 9 The lignocellulose structure and the effect of pretreatment (Mosier 2004)[2]

In order to make the compounds in the biomass more available for hydrolysis in anaerobic digesting, the lignocellulose complex needs to be torn down by the bacteria. This can be facilitated by introducing a pre-treatment step before the actual digestion. Different pre-treatments and purification methods can also be combined to get a clean biomass with the right homogenous characteristics for digestion.

Furthermore, the current ways of grass handling along the material flow chain and appearing problems are being discussed. Because the different grass streams can vary in quantity, quality, legal status, mowing conditions and more, it was decided to differentiate four grass categories: agricultural grass, nature grass, roadside grass and grass from water courses.

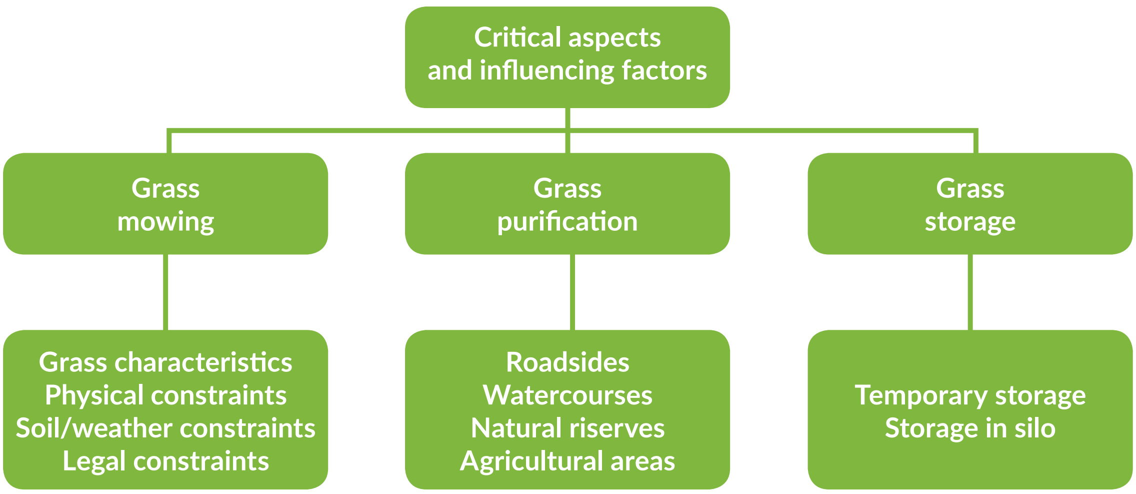


Figure 10 Critical aspects during material flow stream of grass

2 References: Mosier, N., Wyman, C., Dale, B., Elander, R., Lee, Y.Y., Holtzapple, M., Ladisch, M. (2004). Features of promising technologiesfor pretreatment of lignocellulosic biomass, Bioresource Technology (96): 673-686.

Herbaceous biomass resources are typically available on an agricultural field and, before being converted to an energy carrier, it will need to be brought to an energy plant. This requires a series of steps to be performed before energetic valorization that depends on the final process requirements, the biomass characteristics and economic considerations. Harvesting, storage and some sort of transportation are almost always included in the supply chains of herbaceous biomass. In general it is important to consider that:

- harvesting of herbaceous biomass can be typically performed in a very narrow time span, mainly due to weather conditions which can make its application impractical or impossible;
- herbaceous biomass is available only for a specific period in the year and needs to be stored up to 12 months before its usage;
- low energy density of herbaceous biomass is an important factor, negatively influencing the overall economics and thus limiting potential applications;
- the transport distance is likewise limited and the energy plants tend to be much closer to the source of biomass.

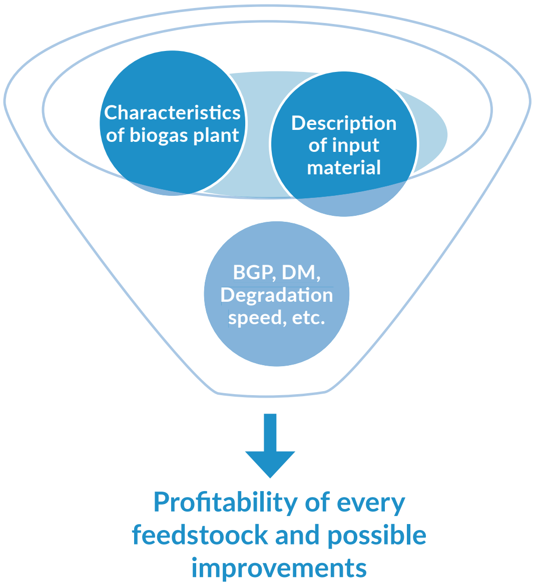
Grass can be one of the main feedstock for anaerobic digestion and biogas production on an European perspective beside industrial, municipal and agricultural organic waste. Once produced, biogas can be divided into two grades: raw biogas (CH_4 55–65 % and CO_2 35–45 %) and upgraded (CH_4 >90 % and <10 % other gases), called biomethane.

After appropriate pre-treatment biogas can be used in loco, for producing thermal and electric energy, or it can be stored. Biogas can be eventually upgraded and use as high grade biofuel or injected in the natural gas grid.

Profitability calculation tool

The GR3 Project has developed and validated, through specific case studies and field tests, a biomass quality prediction protocol to predict the suitability of grass residues for biogas production related to their origin and morphological characteristics.
In the same way has been implemented a Profitability Calculation Tool which can be used by plants owners and operators to evaluate the techno-economic feasibility of using grass residues as a feedstock for biogas production.

The document is ready to use and available for free in a user friendly Excel format. The following picture report a couple of screenshots taken using the Profitability Calculation Tool (Figure 11).



General Information

Volume reactor	3000	m^3
Cost digestate	100	Euro/ton DM
Biogas price	0,4957	Euro/m^3

Feedstocks

	Type	Ton FM/day	Price per ton FM
Feedstock 1	Manure	50	-14
Feedstock 2	Maize silage	20	35
Feedstock 3	Grass silage	5	-20
Feedstock 4			
Feedstock 5			

Specifications for grass		
Type of grassland	Storage	Month of mowing
Roadside	Pile (<5d)	April

Figure 11 Profitability Calculation Tool (input data).

Environmental and socio-economic analysis of grass residue to biogas chains

Overall bioenergy potentials

From the results of the regional potentials and the biochemical methane potential, the regional energy potential could be estimated. From this estimate, the national and European potentials were extrapolated, on the basis of literature data and European databases.

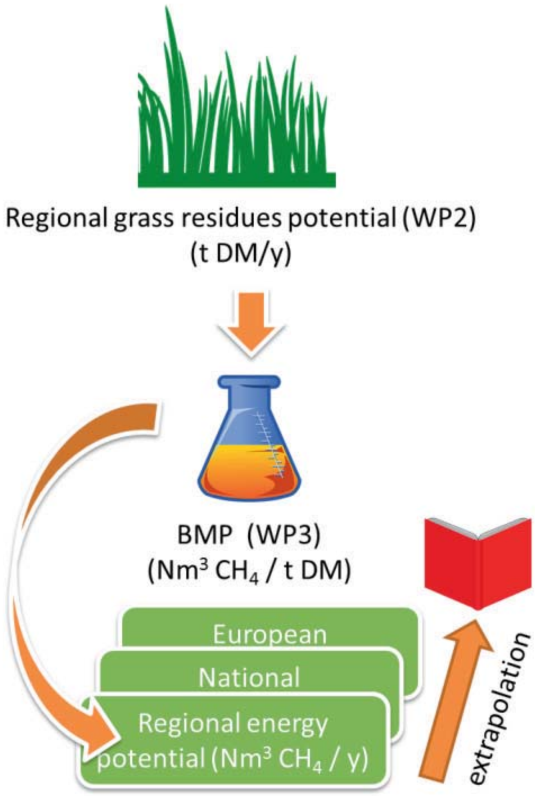


Figure 12 Estimation of biomass potential

Inventory of biogas plants

This task includes an inventory of the main biogas plants in GR3 countries using grass. Some of these biogas plants invested in storage, purification and/ or pre-treatment technologies for grass residues. Furthermore, some of them contributed to match-making between sources of grass residues and biogas plants.

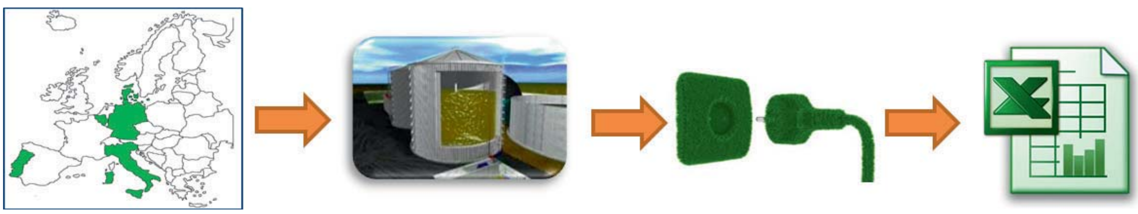


Figure 13 Inventory of biogas plants in the GR 3 countries

Creation of jobs and social economy

The employment analysis focuses on the use of grass, originating from roadside verges, for the production of biogas in Flanders. It looks at the extra jobs that could be created in the supply chain on the one hand, and on the biogas plants that process the grass, on the other hand. For the biogas plants, we took in to account an average plant that processes 60,000 tons/year, of which 6000 tons could be grass.

In the supply chain, three types of jobs were distinguished: the mowing, the transport and the pretreatment. Pretreatment describes all necessary processes to remove disturbing pollution, such as litter and soil. Approximately 121 609,81 tons of fresh grass residues from roadside verges are available each year in Flanders. To mow this amount of grass, 26.35 FTEs (Full Time Equivalents) are necessary. In the ideal situation, all the grass within a circle of 14 km around the biogas plant is transported to that plant. This means work for 11,55 FTEs. Finally, during the pretreatment, 1,55 tons of grass can be processed by one person in one hour, resulting in 50,67 FTEs for the whole region. Pretreatment is typically a job that can be performed by low skilled employers.

For biogas plants, the needed FTEs are calculated per produced TWh/year. If a plant takes up 10 % of grass, 6,8 % of its gas output can be assigned to grass. This means that for the Flemish region 3,45 FTEs for construction and 10,13 FTEs for maintenance of the plants can be assigned to the use of grass.

In other words, the equivalent of approximately 102 FTEs could be created by taking up large scale digestion of roadside grass residues in Flanders. However, there remains the fact that it isn't likely that extra work would be created in both mowing works and transport, as these should already be carried out under the current Flemish legislation. Furthermore, the same can be said for existing biogas plants. These existing jobs would become dependent on the digestion of grass, rather than other feedstocks for the digestion process.

Furthermore, it has been remarked that the total potential for roadside grass residues, which was estimated in the inventory of the GR3 project, is an underestimation (Pasmans, et al., 2014). This is mostly due to the fact that certain verges are either not mown, or their clippings not collected or disposed. Of course, this also results in an underestimation of the employment potential that could be achieved in a valorization scenario.

Even so, according to the available data more than 50 jobs could be created in the sector of social economy, through the employment of laborers in the pretreatment of grass residues. As this concerns long term, stable employment, this provides a significant opportunity for low-skilled, disadvantaged laborers.

Life cycle assessment

In this task, a consequential life assessment (LCA) is performed for five management scenarios of meadow grass from natural areas, otherwise left un-harvested (reference management).
These scenarios are: anaerobic digestion, composting, animal feeding, integrated generation of solid fuel and biogas (IFBB) and a green biorefinery concept (production of protein and energy). The environmental impacts of these five grass management strategies on global warming, acidification, marine and freshwater eutrophication are summarized in the LCA report, available on the GR3 website.

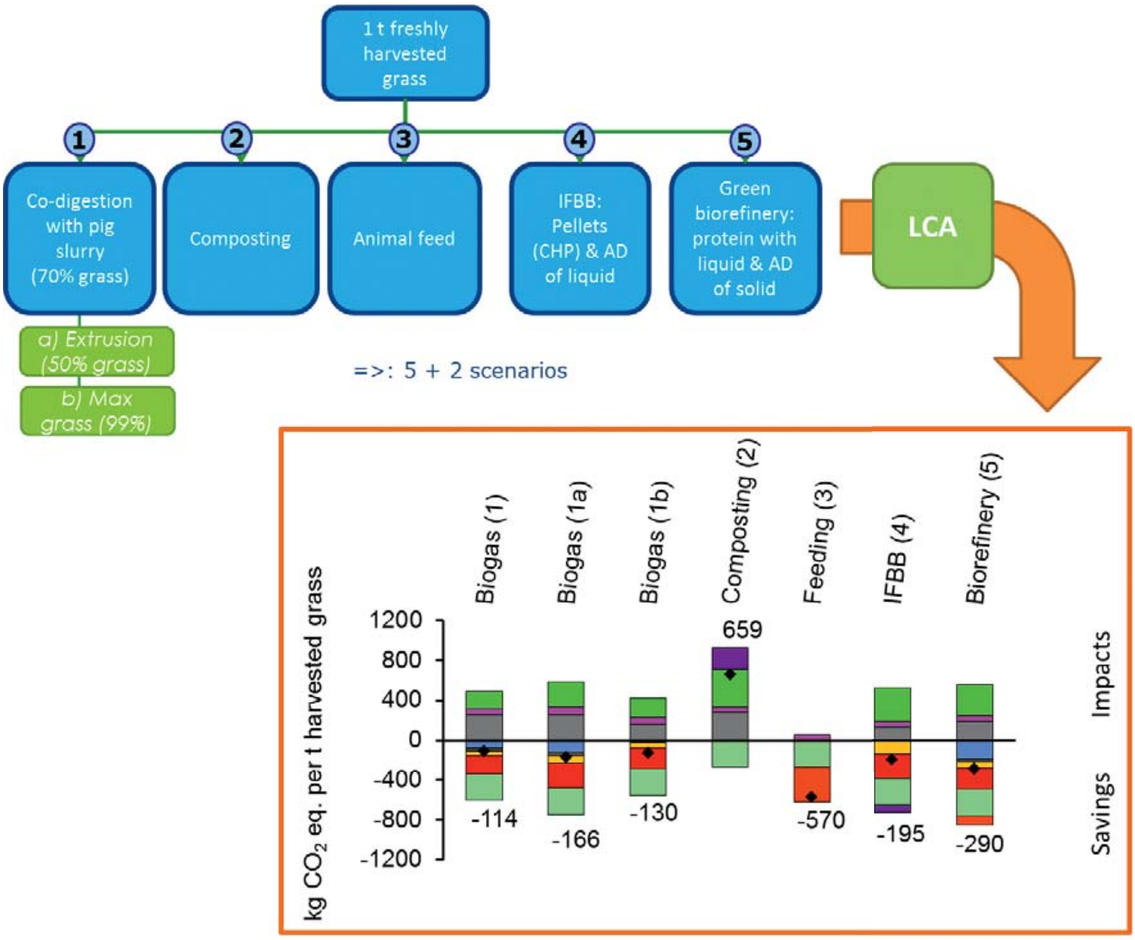


Figure 14 LCA Scenarios

Cost Benefit Analysis

In this task, a cost-benefit analysis (CBA) was performed on the above-mentioned LCA scenarios, with the exception of the biorefinery scenario, which is here replaced by a dry fermentation scenario where grass is the sole substrate. The findings of this task are summarized in the CBA report, available on the GR3 website.

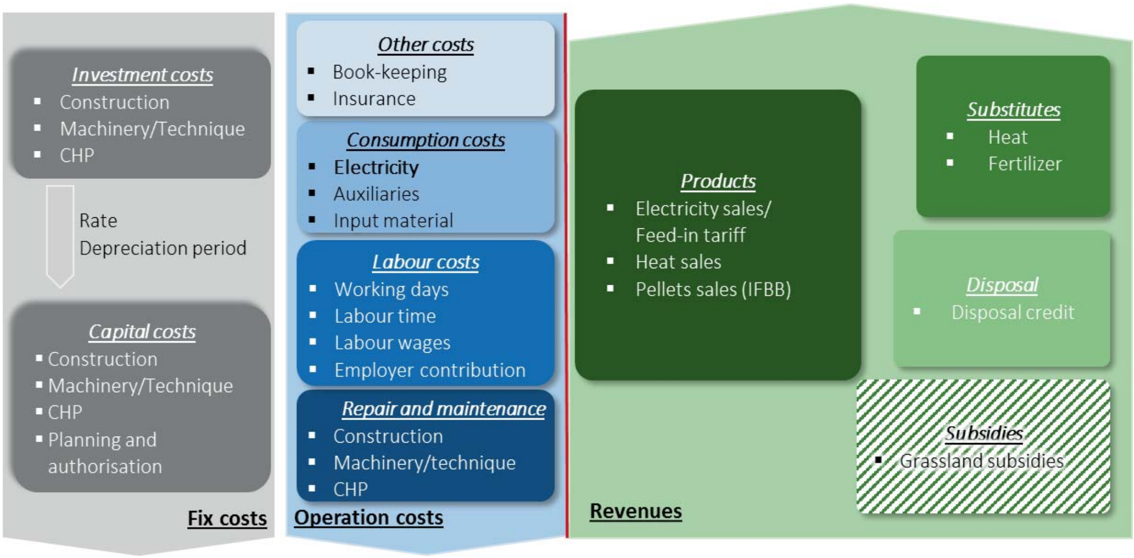


Figure 15 Cost-Benefit-Analyses

Finally, the best alternatives for the selected scenarios in the partner countries are those with the most technical input. If biogas plants process the grass residue, the profit turns out to be the highest. However, the technical equipment is very expensive and the system is difficult to run. However, in Germany the highest profit can be achieved with biogas plants. A composting plant has to produce very efficient fertilizer to be as profitable as a biogas plant.

Benchmarking optimal grass valorisation chains

The key output of this task is three manuals informing different categories of stakeholders about the optimal way of implementing biogas value chains from residual grass. The three categories of stakeholders targeted include grass suppliers (nature conservancies, municipalities) and biogas plants. These manuals are available free of charges on the GR3 website.

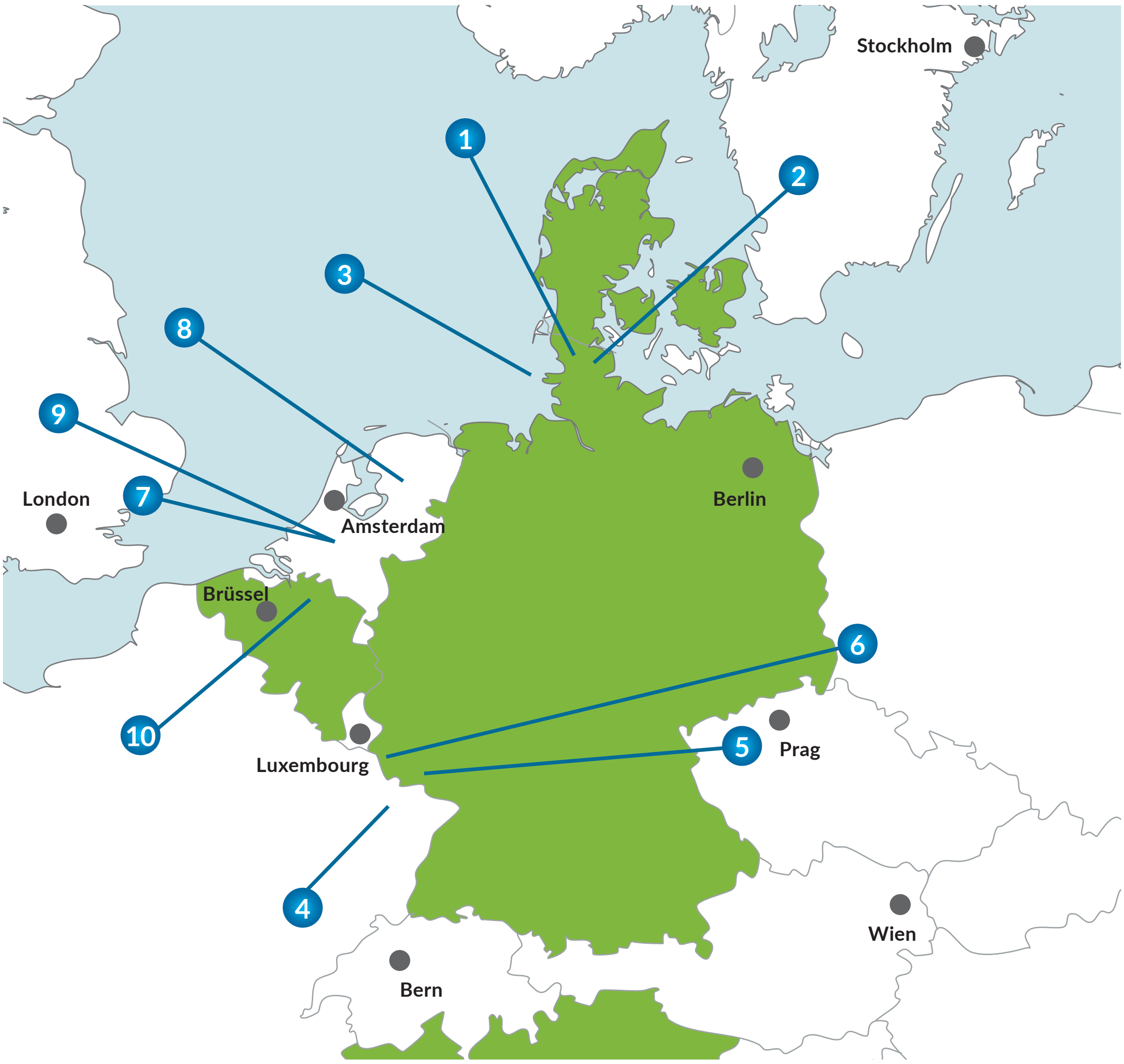
Figure 16 Benchmarking optimal grass valoristaion chains

Business development

Proof of principles – Studytours

Although the digestion of grass is an innovative and under-utilised way of valorisation of this type of biomass, there are already some installations operational in Western Europe. During the GR3 project several visits to some of these installations were organised for those interested.

In this chapter you can find some information on these installations that already digest grass that were visited. For more detailed information, please check information on the website.



Vollstedter Biogasanlage GmbH & Co.KG

Nr. 1 on the map

Location	Nothern Germany (Vollstedt)
Type of digester	Wet digester (agricultural)
CHP capacity	500 kWe
Feedstock	40 % grass waste
Special features	Imprasyn Technique Heat used for district heating

Bi.En GmbH & Co.KG

Nr. 2 on the map

Location	Nothern Germany (Kiel)
Type of digester	Wet digester (agricultural)
CHP capacity	None – biogas is consumed in heating system
Feedstock	40 % grass waste
Special features	BtE process: separation of grass with digestion of the liquid phase and briquetting of the solid phase

Wilstermarsch Energie GmbH & Co.KG

Nr. 3 on the map

Location	Nothern Germany (Aebtissinwisch)
Type of digester	Dry digesters
CHP capacity	526 kWe
Feedstock	60–80 % grassilage (20–40 % maize)
Special features	Garage type digester (8 boxes) LOOCK system Collective ownership (14 farmers)

Sydeme Méthavalor

Nr. 4 on the map

Location	Western France (Forbach)
Type of digester	Dry digester (communal waste)
CHP capacity	± 1200 kWe
Feedstock	10 % grass residues 10 % industrial waste 80 % organic household waste Total: 45.000 ton/year
Special features	Kompogaz technique Part of the biogas to biomethane (50 Nm^3/hr) Production of compost and liquid fertilizer Multiflux collection technique

Bannsteinhof

Nr. 5 on the map

Location	Germany (Zweibrücken)
Type of digester	Wet digester (agricultural)
CHP capacity	180 kWe
Feedstock	60 % grass residues 40 % manure
Special features	Single-farm installation Digestate used on own land

Bioenergie Schneider GmbH & Co.Kg

Nr. 6 on the map

Location	Germany (Kusel)
Type of digester	Dry digester (agricultural)
CHP capacity	330 kWe
Feedstock	33 % grass residues 67 % maiz and grain silage
Special features	Garage box system (5 boxes) - Bekon Own on-farm biogas plant Heat for wood drying + district heating

Erk Energy

Nr. 7 on the map

Location	The Netherlands (Zeewolde)
Type of digester	Wet digester
CHP capacity	800 kWe
Feedstock	50 % manure 50 % other materials (of which 25 % grass, 25 % grains and 50 % flower bulb waste
Special features	Feedstock is first fed to a buffer in which it is mixed and in which hydrolysis takes place An special “vacuum pump” is used to pump the feed-stock and digestate to the different compartments – these pumps are much less sensitive for pollution

Accres Vergister

Nr. 8 on the map

Location	The Netherlands (Lelystad)
Type of digester	Wet digester
CHP capacity	120 kWe
Feedstock	Variable, e.g.: 55 % manure 23 % grass 22 % other
Special features	Research purposes A shredder of the type “molares” was used as a pre-treatment for the biomass, which leads to a 15 % increase of biogas.

v/d Knijff

Nr. 9 on the map

Location	The Netherlands (Zeewolde)
Type of digester	Wet digester (plug flow)
CHP capacity	2 x 700 kWe
Feedstock	50 % manure 50 % other products (of which 40 % solid substances (such as grass, flower bulbs,...) and 60 % liquid products (such as starch, slaughterhouse sludge,...))
Special features	a shredder of the type “molares” was used as a pre-treatment for the biomass

IGEAN

Nr. 10 on the map

Location	Belgium (Brecht)
Type of digester	Dry digester
CHP capacity	3 x 705 kWe 1 x 290 kWe“
Feedstock	Waste grass (up to 25 %) Organic Household Waste
Special features	OWS technology

Reactions from participants

In total 41 people joined the study tours organised within the GR3 project, ranging from people interested in investing in an installation, up to people looking for a good way of disposal of the grass waste. The main reactions were very positive – below you can find a selection of the reactions.

“The visits did provide good and helpful information”

“It will help for future development of our project”

“Visiting existing sites is very helpful for practical concerns and opportunities”

Workshops

Check with the „real world“

As the GR3 project is about the implementation of grass-digestion in practice, it was important to have the ideas and possibilities checked and discussed with people that work with the matter on a daily basis. In order to do this several workshops were organised throughout the regions and the project. The main aim of these workshops was – besides providing the so far gathered information – also receiving feedback from the audience. In the figure below you can find some of the most remarkable in- and outputs of these workshops. For further information (powerpoints, etc.) – check the website!

Facts & figures

- We were happy to welcom 488 people to our different workshops throughout the project’s lifetime;
- All workshops had a very positive evaluation (> 75 %)
- Numerous presentations were given to have a good overview over the different points of view concerning the matter;
- All presentations given at the different workshops are to be found on the GR3-website!

Technology check

One of the main concerns for having grass digested is the quality of the material delivered at the digester site. This latter prefers the biomass to be free of sand (and other contaminants) and chopped to small pieces (<1 cm) before feeding it to the digesters. When mowing the grass, a lot of impact on the quality is to be expected from the type of mowing technology that is applied.
In order to shed some more lights on this 'technological' point of view from the chain, 2 technology-workshops were organised, 1 in Flanders and 1 in Italy. There was a lot of response to these workshops, as over 140 people showed to be interested in these demonstrations.

Business plan development

The main aim of this GR3 project was to develop the actual digestion of grass in different regions throughout Western-Europe. Of course, no one will start a "new business" without having it thoroughly checked, i.e. a business plan developed.

In this chapter you will find a summary of the most important cases that were studied within the project. The information given in this document will give you a good overview of the results, though if you would like to have more details on each case – please check the more detailed reports (and also additional cases) on our website!

CASE Noord Limburg

Location	Limburg (Belgium)
Grass supplier	Nature conservancy Agencies (ANB & Natuurpunt)
Type of grass	Natural conservancy areas
Amount of grass available	1.200 Ton/year (fresh material) (calculated with 7 ton fresh material/ha) Actual disposal rate: 0–35 €/ton
Digester	Biogas Bree
Type of Digester	Wet digester (existing)
Capacity	60.000 ton/year – CHP: 1.2 MWe
Business study and evaluation	
Pilot tests	Performed on both grass from spring and autumn. Great difference in "digestability" was noted: the waste grass from spring did not give technical problems, where the fibrous composition of the grass that was mown in autumn did result in problems with the digestate treatment in the digester.
Ensilaging	Is to be considered when mowing big volumes at once (> 5 % of the digester's daily feedstock). If grass can be delivered in smaller volumes, ensilaging is not required.
Cutting	It is very important to cut the grass to a size < 1 mm when feeding it to a wet digester
Dry Matter content Grass	± 32.2 %
Biogas production	130–185 Nm^3 biogas/ton fresh mowed grass

CASE Noord Limburg

Economics	As the exploitation costs for process grass (instead of maize or other OBA) will increase, a significant gate-fee should be demanded. That makes that for those organisations that dispose their grass for free (0 €/ton) there will always be an economic loss when disposing to a digester site.
Conclusions/remarks	
Economic benefits	With a gate fee of 20 €/ton, both partners could make a profit of ± 10 €/ton (Assumptions: grass delivered at the digester site + actual grass disposal at 35 €/ton)
Ecological benefits	Some of the herbs that are problematic for nature conservancies, show to have the highest biogas yield. That might be an opportunity!
Way Forward	
Cooperation	At this moment the cooperation is "on hold", as both partners have now better economical options than the digestion of waste grass. But never say never ...
Legislation	In case the Flemish legislation sharpens, the digestion of waste grass at the site of Biogas Bree will no longer be possible.

CASE ATB Van Der Weehe

Location	Ranst (Belgium)
Grass supplier	ATB Van Der Weehe
Type of grass	Grass from garden maintenance
Amount of grass available	200 ton/year (fresh material) Actual disposal rate: 49 €/ton
Digester	ATB Van Der Weehe
Type of Digester	Wet or Dry digester (non-existing, different scenarios evaluated)
Capacity	1.250–2000 ton/year – CHP: 15–30 kWe (different scenarios evaluated)
Business study and evaluation	
Different scenarios	3 different scenarios were evaluated: Sc 1: grass + organic waste – 1.250 ton/year (Wet) Sc 2: grass + organic waste – 2000 ton/year (Wet) Sc 3: grass + organic waste + road sides grass – 2000 ton/year (Wet)
Process	For the wet digester dilution water had to be included to maintain a good dry matter content in the reactor. Also separation of the digestate in solid and liquid fraction was required. Heat was supposed to be consumed on the site for digestate treatment (evaporation or drying
Disposal of digestate	Thick fraction will be disposed at composting plants (49 €/ton). Thin fraction will be disposed on land (after hygienisation).

CASE ATB Van Der Weehe

Investment	From 493.000 € (Sc 1) to 526.000 € (Sc 2) to 478.500 € (Sc 3)
Exploitation costs digester	From 44.000 €/y (Sc 1) to 63.000€/y (Sc 2) to 35.500 €/y (Sc 3)
Revenues	From 29.000 €/y (Sc 1) to 59.000 €/y (Sc 2) to 56.000 €/y (Sc 3)
Conclusions/remarks	
Economic benefits	Under the actual circumstances there is absolutely no interest in the investment of a (small scale) digester unit at the site of ATB. The dry digester seems to be the most favourable, though still with a pay-back period of over 20 years.
Ecological benefits	For ATB Van Der Weehe it would have been nice if they could valorise the green waste they generate while maintaining gardens as a source for their own renewable energy production
Way Forward	
Investment	Given the negative economic evaluation, the company will not invest in this technology.
Legislation	In case the legislation would change and provide a higher financial support, ATB Van Der Weehe would be interested.

Brussels Airport Company – Guilliams Green Power

Location	Zaventem – Boutersem (Belgium)
Grass supplier	Brussels Airport Company
Type of grass	Grass from airport maintenance
Amount of grass available	1.600 ton/year (fresh material), Actual disposal rate: 50 €/ton
Digester	Guilliams Green Power (GGP)
Type of Digester	Wet digester (existing)
Capacity digester	60.000 ton/year – CHP: ± 1.2 MW_e
Business study and evaluation	
Different scenarios	Sc 1: Own digester at BAC site Sc 2: Disposal of grass waste at existing installation (GGP)
Practical opportunities/issues	Grass is not contaminated (no heavy metals, no plastic, … Grass is frequently cut (airport restrictions – so at diposal throughout the year (mainly summer time) Distance between BAC and GGP: 30 km Crossing the “airport borders” with biomass“
Scenario 1	Digestate would be disposed as fertilizer Investment ± 650.000 € Operational costs: 70.000 €/y Benefits: 150.000 €/y IRR: > 10 % with a payback time of ± 8 year

Brussels Airport Company – Guilliams Green Power

Scenario 2	Gate fee @ GGP: Under negotiation (20–25 €/ton) Benefits BAC: 10–15 €/ton (cost transport + customs: ± 15 €/ton) Benefits GGP: 10–15 €/ton (replacement sludge waste with same biogasproduction and zero gate fee, increased costs digestate treatment – 10 €/ton)
Conclusions/remarks	
Economic benefits	For BAC the most economical solution would be the installation of the small scale digester on the own site. After the paydown of the investment, there would be a benefit of 70.000 €/year. But this is a "long-term" solution. The 2nd scenario would be more feasible on short term – and has significant benefits for both sides.
Technical concerns	From the digester site (GGP) there still are concerns about the impact of the grass digestion on the technical process of the digestate treatment (concerning the fibres). It is now assumed that it replaces an easy to handle organic waste stream.
Way Forward	
Investment of BAC	The company is still further doing studies about the possibilities for grass digestion on their own site.
Disposal of grass to GGP	Gate fee is still under negotiation
Legislation	In case the legislation will further sharpen (obliged hygienisation) the disposal of grass waste to the existing digester site will not be economically feasible any more.

Intermunicipality IVM

Location	Maldegem (Belgium)
Grass supplier	Municipalities
Type of grass	Grass from roadsides
Amount of grass available	± 4.500 ton/year (fresh material), Actual disposal rate: xxx €/ton (confidential) at own composting plant
Digester	IVM (own small scale digester) – different scenarios
Type of Digester	Dry digester (non-existing)
Capacity digester	9.200 to 30.000* ton/year (*including VGF and grass from private gardens + energy crops)
Business study and evaluation	
Different scenarios	Sc 1: Grass digestion (1.000 T/y) at recycling park in Maldegem Sc 2: Grass digestion (15.000 T/y) at the IVM composting site Sc 3: Grass + VGF digestion (16.200 T/y) at the IVM composting site
General	As the composting site of IVM is only allowed to compost "green waste", it is not possible to compost the digestate coming from the (possible) digester on this site. An additional investment (separate composting) would be required.

Intermunicipality IVM

Assumptions	Pure grass-digestion is unlikely – adding equal amounts of corn (25 €/ton) Heat is sold to district heating grid (sold at 0.02 €/kw_{th})	
Scenario 1	Investment: ± 1.000.000 € OPEX: ± 100.000 €/y Benefits: ± 130.000 €/y (year 1–10) Pay Back Period: > 30 years	
Scenario 2	**4.600 ton Grass** Investment: ± 2.000.000 € OPEX: ± 320.000 €/y Benefits: ± 490.000 €/y (y 1–10) Pay Back Period: 12 years	**150.00 ton Grass** Investment: ± 9.500.000 € OPEX: ± 1.000.000 €/y Benefits: ± 1.850.000 €/y (y 1–10) Pay Back Period: 11 years
Scenario 3	**4600 ton Grass + 1600 ton VGF** Investment: ± 2.000.000 € OPEX: ± 360.000 €/y Benefits: ± 570.000 €/y (y 1–10) Pay Back Period: 10 years	**15000 ton Grass + 1600 ton VGF** Investment: ± 9.500.000 € OPEX: ± 1.000.000 €/y Benefits: ± 1.915.000 €/y (y 1–10) Pay Back Period: 10 years

Municipality Beersel

Location	Beersel (Belgium)
Grass supplier	Municipalities
Type of grass	Grass from roadsides
Amount of grass available	± 110 ton/year (fresh material) from roadsides ± 300 ton/year (fresh material) from garden maintenance Actual disposal rate: 55 €/ton
Digester	Beersel (own small scale digester) – different scenarios
Type of Digester	Dry digester (non-existing)
Capacity digester	1.700 to 4.000* ton/year (*including VGF)
Business study and evaluation	
Different scenarios	Sc 1: Digestion of own available flows (grass + VGF) Sc 2: Theoretical scenario with increased volumes, no VGF (2.000 ton/y) Sc 3: Theoretical scenario with increased volumes, no VGF (4.000 ton/y)
Assumptions	Pure grass-digestion is unlikely – adding equal amounts of corn (25 €/ton). Heat is used for heating a nearby building and drying of the digestate
Scenario 1	Investment: ± 510.000 € OPEX: ± 170.000 €/y Benefits: ± 200.000 €/y (year 1–10) Pay Back Period: > 18 years
Scenario 2	Investment: ± 1.000.000 € OPEX: ± 300.000 €/y Benefits: ± 305.000 €/y (year 1–10) Pay Back Period: > 250 years
Scenario 3	Investment: ± 1.700.000 € OPEX: ± 540 000 €/y Benefits: ± 600.000 €/y (year 1–10) Pay Back Period: > 28 years
Conclusions/remarks	
Economic benefits	If the digestate has to be disposed of at the existing VGF-composting facility, it would not be economically advisible to proceed towards a small-scale digester plant for the municipality of Beersel.
Way Forward	
Investment	The payback time for the investment is way too high to support an investment in this type of equipment.

Ökostrom Saar

Location	Losheim (Germany)
Grass supplier	Municipalities and farmer
Type of grass	Grass from landscaping material
Amount of grass available	4.000 ton/year (fresh material) Actual disposal rate: 0–28 €/ton
Digester	
Type of Digester	Wet digester (existing)
Capacity digester	14.000 ton/year – CHP: 500 kW_e
Business study and evaluation	
Biogas Plant	The company uses different amounts of landscaping material. They had problems with landscaping material, which has too many Sand and ground inside. In addition, the grass must cut under 1 cm. Replacement of energy crops For the biogas plant company are only the landscaping material interest with no transport costs and they pay for the material or they by no money for the material and have the transport costs. However, the distance must be under 10 km from the Biogas plant. The reason the low energy in landscaping material.
Conclusions/remarks	
Economic benefits	The Company will us only cheap or free landscaping material because work risk are higher and the production of energy (heat and electricity) is lower than with maize
Way Forward	The company accepted landscaping material and the contract is signed.
Contracts	Willingness to accept landscaping material is confirmed. Contracts will be signed.

SYDEME

Location	Sarreguemines, France
Digester	
Type of Digester	Dry digester (existing)
Capacity digester	15.000 ton/year; 12.000 MWh/year biomethan
Amount of grass available	11.000 ton/year (fresh material)
Business study and evaluation	
Digester site	Replacement of energy crops Costs energy crops: 32–34 €/ton (higher biogas yield and lower DM) Benefit: 5–14 €/ton
Conclusions/remarks	
Economic benefits	The biogas plant are specific build for grass and dry material. With the supply contract, they have save a quantity delivered and have no problems with the logistic organisation to pick and to transport the material.
Way Forward	
Contracts	The company accepted landscaping material and the contract is signed.

EVS, Entsorgungsverband Saar

Location	Saarland
Grass supplier	Municipalities
Type of grass	Grass from vgf collection, landscaping and greenery cuttings
Amount of grass available	11.000 ton/year (fresh material) Actual disposal rate: 44–55 €/ton
Business study and evaluation	
Municipalities	With the supply contract is the benefit between 17–35 €/ton
Conclusions/remarks	
Economic benefits	For the company the supply contract is cheaper (20–27 €/t) than storing the material.
Way Forward	
Contracts	The company accepted landscaping material and the contract was signed.

Azienda Agricola Possamai

Location	Ponte nelle Alpi, Belluna, Veneto Region, Italy
Grass supplier	Self-supply
Type of grass	Grass from landscaping (meadow land)
Amount of grass available	300 ton/year (fresh material) Actual disposal rate: 0 €/ton (left on site after mowing)
Digester	
Type of Digester	Wet digester (newly constructed)
Capacity digester	99 kWe – mainly digesting livestock effluents (16 t/day) Digestate is separated in solid and liquid fraction and applied on land
Business study and evaluation	
Digester site	A new digester plant was evaluated, constructed and started up. The digester consumes grass from (own) meadow land in the neighbourhood. Non-contaminated and as surplus on the feedstock to the digester.
Conclusions/remarks	
Economic benefits	Capital and operational costs AD reactor 800.000 € Utilities (machines) 56.500 € Annual operational costs for AD plant 32,500 €/year Revenues (expected) 180.000 Euros/year for selling 850 MWh per year @ a gross tariff of 236 €/MWh (212 €/MWh net) Expected pay back period Between 5.8 and 6.6 years
Way Forward	
Achievements	The plant is treating some 300 ton/year of grass mowed in meadows and landscape.
Future	Selling of digestate to local winegrowers is under investigation.

Veneto region

Location	Veneto region, Italy
Grass supplier	Municipalities
Type of grass	Grass from landscaping (meadow land)
Amount of grass available	750 ton/year (fresh material)
	Actual disposal rate: 0 €/ton (left on site)
Digester	EUCOmpact by Schmack Biogas Viessmann Group
Type of Digester	Semi-Dry digester (existing) 2x200m^3
Capacity digester	100 kWe – mainly digesting rabbit manure + maize silage
Business study and evaluation	
Digester site	Part of the maize silage was substituted with grass (fresh). The grass was fed starting at the rate of 0,5 ton/d and arriving to stabilize a feeding of 3,5 t/d. Benefit: improved process resilience and feeding cost reduced of 55 €/day considering the cost for feeding with and without grass
Municipalities	Does not apply
Conclusions/remarks	
Economic benefits	Feeding cost reduced of 55 €/day considering the cost for feeding with and without grass
Way Forward	
Contracts	The plant is now processing 750 ton of grass/year
Legislation	If the legislation narrows – that will be an issue and farmers will stop processing the waste grass

Municipality Sønderborg

Location	Sønderborg
Grass supplier	Municipality Sønderborg
Type of grass	Grass from: household garden, public parks & sport courses maintenance, local airport
Amount of grass available	7.000 tonnes / year (fresh material) Actual disposal rate: 141 dkk/tonne; 19 €/tonne (estimate based on Odense Nord until I have data from Sønderborg; conversion rate of 7.4 dkk/€)
Digester	Blans (planned)
Type of Digester	Wet digester
Capacity digester	400.000 ton/y; 11–13 mio. Nm3 CH4/y
Business study and evaluation	
Digester site	Benefit: Assuming biogas plants pay 30 dkk/t; this is what biogas plants are willing to pay today for "excess" grass; considering small cost for shredding ("very cheap, according to a leading Danish biogas plant operator") & silage at 30 dkk/t (transport out, as energy crop also has to be transported). Total: 60 dkk/t. 7.000 t FM grass is equivalent to 1.260 t DM/y (DM: 18 %). Assuming energy crop price of 800 dkk/t DM (incl. transport + silage) | Total price for energy crop (1.260 t DM/y @ 500 dkk/t DM): 136.000 €/y | Total price for grass (7.000 t FM/y @ 60 dkk/t FM): 56.700 €/y Benefit: 136.000–56.700 = 79.500 €/y (inconsistencies due to rounding) Lost biogas potential: | Energy crop (380 Nm3 CH4/t VS; 0.9 t VS/t TS): 430.920 Nm3 CH4 | Grass (300[3] Nm3 CH4/t VS; 0.9 t VS/t TS): 340.200 Nm3 CH4 With 35.2 MJ/Nm3 CH4; 46 % efficiency el; 40 % efficiency heat; 0.089 €/kWh el (2020); 0.04 €/kWh heat Lost benefit on heat/power sales: 239.900 € - 189.400 € = 50.500 € Benefit: 79.500 - 50.500 €/y = 29.000 €/y
Municipalities	Alternative to composting Transport to digester site Benefit: 162.000 €/y (for 7.000 t; income of 30 dkk/t instead of paying 141 dkk/t)
Conclusions/remarks	
Economic benefits	There is a benefit for the biogas plant as long as the grass replaces a substrate at minimum 650 dkk/t DM. There is a clear benefit for the municipality.

| 3 Conservative. To be seen as lower end of the range. Does not consider ensiling and shredding effects.

Amarsul

Location	Municipal district of Seixal - Portugal
Grass supplier	9 Municipalities of the Setúbal peninsula - PORTUGAL
Type of grass	Grass from garden and parks maintenance and also from municipal roadsides provided by the local parish board.
Amount of grass available	20.000 ton/year (fresh material) – 12000 planned to use. Actual disposal rate in landfilling: 30–60 €/ton
Digester	
Type of Digester	Three Dry digesters – thermophilic conditions – Compogas System
Capacity digester	Each digester has a processing capacity of 2.3 ton/h of biodegradable urban wastes. Biogas from digestion is used in CHP. The total electrical production capacity is 8.335 kWh, being fully injected into the electrical power grid.
Business study and evaluation	
Digester site	Feeding the digesters with grass will contribute to increase gas production and improve control of the ammonia content in the digestion process. The Benefit from a ton of grass in terms of electricity is: 15–35 €/ton once electricity is payed at self-consume tariff (7–8 €/kWh) or at the price of the average tension in the electric market (3–4€/kWh).
Municipalities	An opportunity for reducing waste management costs by integrating the collection and transportation of grass within the area served by Amarsul. Also reducing the landfill waste disposal, will contribute to the accomplishment of the national waste targets. Benefit: 40 €/ton for avoiding landfilling (when it is landfilled)
Conclusions/remarks	
Economic benefits	Amarsul intends to strengthen investment in the organic recovery unit in order to achieve targets in the waste area. Investments in digesters has been completed and so new investments will concern only in mechanical processing, by the introduction of new facilities to enable separation of recyclable,
Way Forward	
	Since currently the system only allows the separation of the organic fraction the additional Investment necessary in 2016–2018 is 4 million €. Capital and operational costs are covered by the RSU management system. Considering the technology of the digesters, the increased amount of waste (20 % grass addition) does not change significantly the operation and maintenance costs, ensured by the existing staff and no significant extra capital costs are necessary for grass to AD. This feedstock generates benefits corresponding to about 20 % more biogas production. Amarsul plans to increase the use of grass in the process.

Tratolixo

Location	Sao Domingos de Rana
Grass supplier	Municipality of Cascais, Oeiras, Sintra and Mafra
Type of grass	Residential grass and some Grass from landscaping (meadow land)
Amount of grass available	6.500 ton/year (fresh material) Actual disposal rate: a portion is delivered to the system at 50 €/ton gate fee and another portion has no cost, once is left in place after mowing or dumped, or directed to local composter.
Digester	
Type of Digester	3 Complete mix Wet digester plants planned to work at thermophilic temperature but actually are in operation at mesophilic range. Digestate is centrifuged. The solid fraction is composted and the liquid is treated in the WWTP and reused to dilute the feedstock.
Capacity digester	3.700 m^3 of volume receives Municipal Solid Wastes (75.000 t/y).
Business study and evaluation	
Digester site	The incorporation of more grass increase biogas production. Grass addition improves C/N ratio of the feed and can allow thermophilic digestion increasing additionally by 10–15 % the total biogas production.
Municipalities	The system is planned for 4 municipals and is an alternative to composting. Transport to digester site is ensured by the regional system. The gate fee is high. No Benefit are previewed for the municipality, just more costs.
Conclusions/remarks	
Economic benefits	Capital and operational costs are covered by the RSU management system and does not increase significantly with 10 % grass addition. No significant extra capital cost are necessary. The increased amount of waste does not change significantly the operation and maintenance costs, ensured by the existing staff. This feedstock generates benefits corresponding to about 10 % more biogas production, at least. The increase can be higher: 20–25 %, in case will be possibly to establish thermophilic process. The Benefit from a ton of grass in terms of electricity is: 15–35 €/ton once electricity is payed at self-consume tariff (7–8 €/kWh) or at the price of the average tension in the electric market (3–4 €/kWh).
Way Forward	
Investment	60 million of Euro was the investment for the entire system TMB, Anaerobic digestion, composting, and wastewater treatment. No significant extra investments are necessary for incorporating grass into the system.
Legislation	Grass waste is classified as organic waste in Portugal– This limits possibilities for digestion, once the gate fee requested (50 €/t) discourage grass collection and make not possible a valorisation chain between the grass producer and the plant operator.

ALGAR

Location	ALGAR – Valorização e Tratamento de Resíduos Sólidos S.A. Barros de São João da Venda, 8135-026 ALMANCIL - Portugal
Grass supplier	Municipalities from Algarve region
Type of grass	Residential grass and some Grass from landscaping (meadow land)
Amount of grass available	35.000 t/y (fresh material). 5.000 t/y estimated for Anaerobic digestion. RSU treated BY AD plants: 20.000 t/y Actual grass disposal rate: Composting 15.000 t/y; landfilling 20.000 t/y with biogas production
Digester	3 Complete mix digester plants planned to work at mesophilic temperature. Digestate is centrifuged. The solid fraction is composted (5.000 t/y) and the liquid is treated in the WWTP and reused to dilute the feedstock.
Type of Digester	Wet digester provided with two 400 kW generators
Capacity digester	2x1.500 m^3 receiving Municipal Solid Wastes (20.000 t/y).
Business study and evaluation	
Digester site	The incorporation of more grass increase biogas production from the added biomass. Grass addition improves C/N ratio of the feed increasing by 20–25 % the total biogas production. The Benefit from a ton of grass in terms of electricity is: 15–35 €/ton once electricity is payed as self-consume or at the price of the average tension in the electric market.
Municipalities	The system is planned for the Algarve municipalities and is replacing landfilling. AD is processed jointly with composting. Transport to digester site is ensured by the regional system. No other benefits are previewed for the municipality, just more costs.
Conclusions/remarks	
Economic benefits	Capital and operational costs are covered by the RSU management system. The addition of 10 % grass biomass generates benefits increasing by 10 % the biogas production or 20–25 % in case will be possibly to establish thermophilic process. No significant extra capital cost are necessary and the increased amount of waste does not change significantly the operation and maintenance costs, ensured by the existing staff.
Way Forward	
Investment	1,07 million of Euro (65 % financed by cohesion funds) was the investment for the Anaerobic digestion, composting, and wastewater treatment. No significant extra investments are necessary for incorporating grass into the system.
Legislation	Grass waste is classified as organic waste in Portugal– This limits possibilities for digestion, once the gate fee requested (40 €/t) discourage grass collection and make not possible a valorisation chain between the grass producer and the plant operator. However in Algarve region authorities are interested on increase recycling rate and some promotional measures will be taken.

ERSUC

Location	Ersuc – Resíduos Sólidos do Centro S.A, Rua Alexandre Herculano, 21-B-Sé Nova, 3000-019 COIMBRA
Grass supplier	The two ERSUC Plants receives Municipalities from Aveiro and Algarve Districts. Are negotiating extra supply with Estradas de Portugal for AD and composting units.
Type of grass	Grass from roadside from Estradas de Portugal and garden grass.
Amount of grass available	5.000 t/y (fresh material). 2.500 t/y estimated for Anaerobic digestion. RSU treated BY AD plants: 20.000 + 20.000 t/y. Actual grass disposal is various and carried-out by outsourcing companies
Digester	Two centrals with two complete mix digester plants planned to work at mesophilic temperature. Digestate is centrifuged. The solid fraction is composted (5.000 t/y) and the liquid is treated in the WWTP and reused to dilute the feedstock.
Type of Digester	Wet digesters. Energy production 2x18 MWh/y (average)
Capacity digester	2x1500 m^3 receiving Municipal Solid Wastes (60.000 t/y).
Business study and evaluation	
Digester site	The incorporation of grass increase biogas production from the added biomass and improves C/N ratio, making easier to run at thermophilic temperature. The Benefit from a ton of grass in terms of electricity is: 15–35 €/ton once electricity is payed as self-consume or at the price of the average tension in the electric market. Green road materials will also be used for composting. Actually ERSUC pays approximately 10 €/ton for structural materials for composting
Municipalities	The system benefits the SW operator and reduces indirectly the costs assumed by municipalities. Road grass will increase revenues from biogas. AD is processed jointly with composting. Transport to digester site is under evaluation with Estradas de Portugal. The gate fee can be removed once ERSUC can valorise in AD and in composting the green material.
Conclusions/remarks	
Economic benefits	Capital and operational costs are not necessary and the increased amount of waste does not change significantly the operation and maintenance routines, ensured by the existing staff. The addition of grass biomass benefits AD processing and biogas production. Green biomass for composting has relatively high market price and the delivery from Estradas de Portugal can be advantageous. Estradas de Portugal can attenuate its cost inherent to green biomass treatment and disposal.
Way Forward	
Investment	No significant extra investments are necessary for incorporating grass into the system.
Legislation	Grass waste is classified as organic waste in Portugal – this limits possibilities for digestion, once the gate fee requested (40 €/t) discourage grass collection and make not possible a valorisation chain between the grass producer and the plant operator. However in this case the ERSUC looks this biomass as an opportunity to decrease composting costs and get more income from energy. Some promotional measures will be taken to encourage the business with Estradas de Portugal.

Policy framework

Evaluation of legal framework and incentives

The main regulations for the different origins of grass refer mainly to European waste definitions. Figure 9 illustrates the different origins of grass, clustered towards grass as greenery cuttings from private and public areas, grass as landscape materials from nature conservation areas and grass as agricultural permanent grassland (Figure 16).

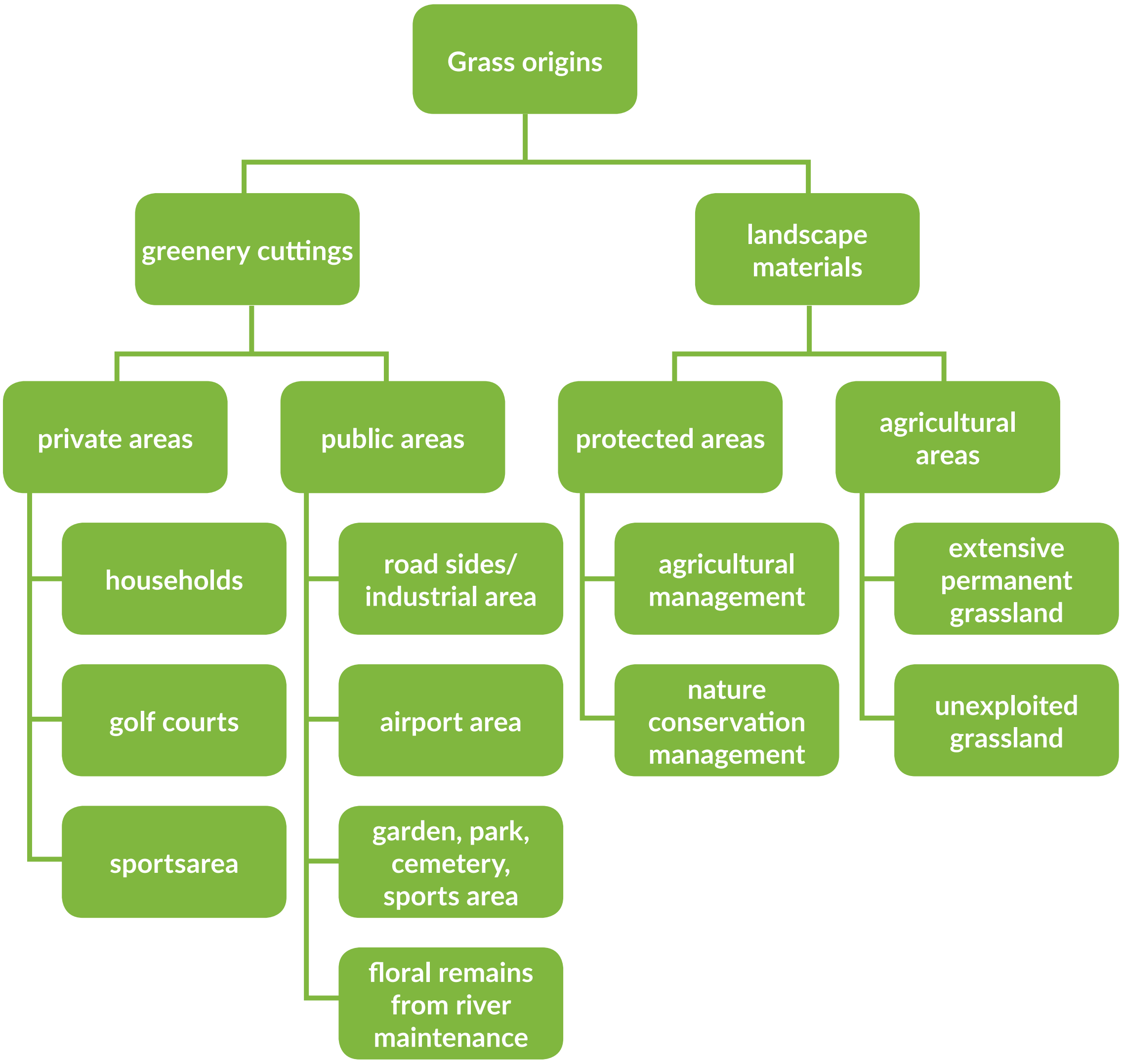


Figure 17 Cluster of grass at its origins

The main EU as well as the national directives on waste management of the different partner countries mainly focus on waste definition, collection and treatment options, approval procedures and application as fertilizer on soils. The Waste Framework Directive (2008/98/EC) legally defines the term organic waste as „biodegradable waste from garden and park area, from household's food and kitchen, from restaurants, caterers and retailers and similar waste from food processing".
Generally bio-waste shall be separately collected "if technically, environmentally and economically practicable. European legislation still allows incineration[4] and landfilling[5] of bio-waste under certain requirements, but facilitates national legislation on separate bio-waste collection and biological treatment in order to produce environmental safe compost and other materials from bio-wastes. It is common, that in many countries landfilling of bio waste is still common state of the art.

The operational responsibility of bio-waste collection shall be organized by single Member States waste management legislation. The concerned bio-waste treatment facilitates in this study are composting and anaerobic digestion, whereas composting is considered as recycling, when the compost is used for fertilizing soil applications. Anaerobic digestion is categorized as energy recovery. Further mechanisms allow to set quality criteria for compost. The acceleration of bio waste as a sustainable resource for bioenergy supply is stipulated in the Renewable Energy Directive (2009/28/EC). Grass as a residue is defined under the biomass definition (biodegradable fraction of municipal waste) and hence eligible and accountable in the national renewable energies share calculation to fulfil the country specific climate protection targets. The following figure describes the different regulations, which affect grass digestion. The flags indicate each GR3 project country.

4 The incineration of bio-waste is regulated in the Waste Incineration Directive (2000/76/EC) with limiting emission thresholds.

5 The Landfill Directive (1999/31/EC): Member States have to reduce the amount of biodegradable municipal waste to 35 % of 1995 levels by 2016 (for some countries 2020), requiring the diversion of biodegradable municipal waste from landfills.

	🇩🇰	🇧🇪	🇮🇹	🇩🇪	🇵🇹
Incentive fpr renewable energy (electricity) production					
• Feed-in tariff system	★		★	★	★
• Quota certificate system		★			
• Extra incentives/restrictions on heat use		★	★	★	
Grass a waste					
• More specific national organic waste definition		★	★	★	
• Separate (regularly paid off) municipal collection	▨	★	★	★	▨
• Bring system to municipal greenery parks	▨	★	★	★	▨
• Mututal collection with household waste	▨				▨
• Gate-fee for grass	▨	★			★
• Extra incentives for renewable energy production			★	★	
Grass as a product					
• Extra incentives for renewable energy production				☆	
• Gate-fee for grass					★
Restriction on digestate management dependently on different grass origins			★	★	

Legend: ★ legally valid since 2014 ☆ legally valid for biogas plants installed before July 2014
▨ dependent on municipalities

Figure 18 Comparison legal framework in GR 3 countries[6]

6 The European term definition refers to the single places of origin and not to the single input biomasses. The GR3 target countries generally comply with this definition in their National waste legislation being split into more details the more recycling requirements exist.

Incentive legislation to valorize grass are existing – either by feed-in tariff systems or quota systems

Grass as an input material in biogas plants can be used and is registered as biomass input material to receive either the national feed-in-tariff or green certificates in quota schemes. Most of GR3 countries have implemented a feed in tariff legislation where fixed price/kWh of biomass electricity is guaranteed for a designated time. Both instruments are steering directly the electricity production from biomass via the use of conversion technologies. Special attention is given to bio waste input materials by higher price/kWh payments in comparison to general non-waste biomasses. No countries beside Germany differ between grasses from certain origins in order to claim for different feed in payments. Only Germany had established a differentiated incentive model where the place of origin of biomasses is indicating an extra feed-in tariff (EEG 2009–2013). With the amendment of the feed-in tariff 2014 (EEG 2014) there are no extra tariffs for landscaping materials any longer eligible. Only grass under the waste tariff requirements will keep on being higher numerated.

Systematical collection service by municipals or third parties

The collection of bio waste/greenery cuttings show similarities across the GR3 European Countries as in all countries a separate collection service by municipalities in place. Different systems according to a pick-up or bring system as well as a mutual collection with residual food and kitchen waste are provided. Also in terms of technical requirements in treatment processes (stabilization and hygienization processes), the quality of the resulting fertilizers/digestates as well as the eligibility for bio waste incentives are pending in function of the collection of biowaste. Specific attention should be given to landscaping materials and greeneries from verges. Landscaping materials from nature conservation areas are mainly commissioned to third parties for maintenances of landscapes. This mainly leads to non-holistic data of current landscaping material amounts and recycling schemes. Also the collection of greenery cuttings from roadsides is not homogenous in all GR3 countries as there are removal regulations in some countries as well as opponent guidelines in other countries to leave these materials at the roadsides (mulching).

Different treatment requirements for grass

No GR3 target country stipulates anaerobic digestion as the sole technical conversion process, although waste or fertilizer legislation could have a direct steering impact in terms of bringing mass flows into high resource efficient treatment (anaerobic digestion). Currently as an example, the German waste treatment legislation prohibits the direct applications of grass on soils and stipulates the thermophile composting or digestion treatment. In contrast to this national legislation, grass is still allowed or tolerated to be landfilled or directly applied without treatment (mulched) on soils in some GR3 target regions.

Public financing strategies for the integration of social employment in biomass chain

In general, social economy aims to meet the needs of people rather than trying to maximize investor profits. Social enterprises generate an increase in social capital and they provide an increase in market competitiveness, by providing alternatives to consumers, lowering prices and allowing skill development and innovation. Finally, they are instrumental in widening the supply of social goods and services, providing new employment opportunities and generating income growth.
Within the biomass supply chain, as described in the GR3-project, it is possible to profit from the advantages the Social Economy can supply. As a general rule of thumb, one can assume that labour intensive tasks, making use of little to no machinery, are ideal for SE employees, as regular companies will often be less interested in these tasks. Here, we're thinking of obstacle mowing along roadside verges and removing the litter from the biomass. They can also provide the logistics to get the grass to the processing entities as fast as possible. This will often mean daily transport of small amounts of biomass, which are not interesting for regular enterprises. Recycling parks can provide important amounts of digestible biomass, when triaged well. Also here, social economy workers can assist the citizens.
One of the main challenges for SE remains the access to financing. There are two main strategies which can be used. First, Services of General Economic Interest (SGEIs) provide a way of public financing of SE without this being designated as competition disruptive state aid. It is clear that these SGEIs should meet several criteria. An example of such a service is realizing certain parts of the conservation objectives in the context of Natura2000, which are difficult or impossible to organize through normal public procurement. Secondly, Socially Responsible Public Procurement (SRPP) is also of interest, as this allows for the social objectives of SE companies to be taken into account when an authority assigns a public contract. Thus SE companies can obtain an advantage in procuring public contracts. At present four possible ways exist to take into account social considerations in public contracts; firstly, when determining the subject-matter of the public contract, or the technical specifications in it. Secondly, by selecting certain companies which comply with certain (social) standards. Thirdly, through the awarding criteria. And lastly, by implementing certain standards in the execution of the contract.

SWOT analysis

The five participant countries have verified that a considerable amount of grass cuttings is poorly valorised in Anaerobic Digestion (AD). Either this substrate can be planted for several reasons as soil protection or conservation against erosion and aesthetic, or it occurs from natural vegetation (e.g. roadsides, natural parks) and has to be maintained for assuring bio-diversity. Green cover crops have many positive effects on the environment. Furthermore is available both close to the cities and on the countryside, offering an opportunity to increase biogas production. It is crucial to know about the possible cause of this lack of interest, namely to identify the non-technical barriers (NTBs) that hinder the investments. Consequently, in this study the identification and role of non-technical barriers and drivers facing the use of grass cuttings in anaerobic digesters was investigated.

To achieve this overall objective and understand why investments concerning adding grass cuttings are uncommon, the project sought to discover whether a range of factors and perspectives on biogas, held by the involved stakeholders, might currently act to inhibit the use of grass cuttings in existing and new AD plants. This are essential information for planning adequate measures to overcome problems. The factors which hinder the investment can be numerous and related to different areas and countries. The key question is to outline an appropriate methodology capable to uncover and identify these non-technical barriers.

In this project, data were collected on the inventorying of grass residues, the best practices and available technology, environmental and socio-economic analysis, business development, legal framework and policy support. All these reports constituted the main source of information for the preparation of the SWOT analysis. This information was extended with data taken from SWOT- surveys. Moreover, a search in the literature data and consultation of energy and waste experts and companies were the additional means used to uncovering attitudes. These actions, in particular, provided figures about the perceived costs and the benefits of grass appliance over other alternatives, the state of knowledge of consumers and agents about grass for AD, and the characteristics of the companies, which processes and uses green wastes. After collecting all this information a specific framework for each country has been done, containing positive (Strengths and opportunities) and negative features (Weaknesses and Threats, referred to as ”Non-Technical Barriers” (NTBs). This methodology enabled to identify and evaluate the factors, which hinder or promote investments, providing data suitable for planning appropriate measures.

The processed SWOT analysis indicates that Anaerobic Digestion is well developed and mature technology in Germany, Belgium, Denmark and Veneto, having many digesters which can process the grass together with others substrates. However, the incentives for biogas production are declining and not enough to promote collection of grass for AD, making the investments clearly not feasible. In Portugal AD application is still limited and there is potential for growth, namely in the area of solid wastes. There are many legislative instruments regulating the grass a substrate, affecting the use in the digester and the digestate application. Grass from urban area and roadside is assumed as a waste, has to pay a gate fee to be delivered to the regional waste system, and requires severe analytical control, making complex and risky the management of the cycle of grass valorisation. Grass management can have chances for application when the environmental classification and rules will promote it.

Policy Proposal

Each policy proposal is based on the results of the SWOT- Analysis, stakeholder interviews and current policy developments. It considers the opinion of different policy makers in each region of how to improve policy endorsements towards an implementation of grass value chains. The main governmental actors were public agencies involved with waste, composting, energy, municipalities, work and social economy. The results of these interviews showed that there are two different levels of required action: one is specifically directed to the legal status of mowed grass, while a second one is related to the necessity to subside the use of such substrate.

These two actions can respond to a number of goals defined from European institutions:

- Renewable energy from biomass which is not used for food/feed purposes is produced
- Organic waste or residual material is recycled: beside methane also digestate rich in nutrients which can be used as a fertilizer is produced
- A number of job opportunities are created along the chain of grass management. Most of these jobs can interest social workers thus enforcing inclusive concepts.

Feasibility studies

In cooperation with the municipality of Beersel, the feasibility of a dry pocket digestion system, which would be able to process grass wastes, will be researched. Dry digestion is a robust process, which is also seen as the BAT for disposing of roadside grass residues by the Flemish Waste Regulation Agency (OVAM). Local processing of the residues will further enhance the capacity of grass residue valorization to reduce GHG emissions, through reduced transport of waste residues.

A number of synergies could be developed this way:

- The Manchester site, an old industrial terrain, is being reconverted to an SME zone. A Flemish research project MIP- Heatroad, is looking into the possibilities of developing a heating network in this SME zone. The heat that is a byproduct of biogas burning in a CHP engine could therefore be utilized in situ.
- Beersel also has a warehouse on the site, which could act as a consumer of heat and electricity produced by the CHP.

The target of this study was to ascertain whether it is feasible for Beersel to process its grass residues, green wastes and/or VGF wastes in pocket digestion, resulting in part of the energy requirements of municipality infrastructure. The aim is therefore to produce energy (electricity and heat) from local waste biomass. These waste streams are present at the recycling park.

The costs and benefits of the digestion of biomass are calculated. Costs involve the extra work needed to manipulate the biomass in the recycling park (sorting, ensilaging, feeding the digester) and extra investments (excluding digester and CHP), such as facilities for ensilaging. Benefits include savings on electricity and heating, but also profits from heat that can be valorized through the heating network and from green power certificates. Gatefees can influence the feasibility of this project. Hence, it was one part of the study to investigate variable gatefees, depending on the biogas potential, but also on the fact if the biomass can digested in a dry pocket digester without adaptation of the legal frame (e.g. VGF vs. pure grass).

In Germany another feasibility study was done, addressing a differentiated system of land owner management fees. Drinking water production is an important. Even though as nearly 70 % of the drinking water in Germany comes from groundwater or spring water, 30 % are provided from surface waters. All water sources need to be analyzed and as required cleaned. The cleaning of the water especially the technical cleaning produces costs. These costs could be saved or better reduced if more grassland that is permanent is established in water procreated or surrounding areas. Furthermore, limitations of mineral or organic fertilizer use should be supported.

Against this background, the use of grass silage in biogas plants and the related preservation of (extensive) permanent pastures is of particular interest. Therefore, the study calculates the production cost of grassland versus corn silage and works a cost analysis of a model biogas plant (500 kW and 8.000 h/a) out. For the grassland, three scenarios were adopted: areas with a yield of 3 t/ha DM grass, 4 t/ha DM grass and 5 t/ha DM of grass. The assumed corn yield is 14.6 t/ha DM. By comparing the different profit of grass silage with corn silage or solely corn silage as a biogas substrate, the amount of the required subsidy for using grass silage economically equivalent to corn silage is concluded. Based on that grass from permanent grassland requires subsidies of around 245–436 €/ha according to the grass yield and the amount of input material. The low cost are only possible without opportunity cost. Now the regional subsidies for preserving grassland paid by the federal state Saarland are between 102–316 €/ha. The other part of the feasibility study shows that only between 8 and 17 ha of corn silage can be replaced with grassland. Compensating a higher amount of corn by grass is inefficient, as with increasing distances between field and biogas plant the higher transport costs won't be covered. One option for (partly) filling the gap – especially in areas where the extraction and treatment of clean drinking water is difficult and expensive – could be the drinking water management companies. However, even there the regional circumstances, particularly the natural renewal of water, must be taken into account.

Communication and dissemination

The dissemination of lessons learnt and the project results to national and regional stakeholders occurred through the project website, electronic newsletters, participation in external conferences and organisation of regional final conferences for stakeholders and the final conference in Belgium (Gent) in the middle of March 2016. Due to different languages, the involved partners participated in the dissemination of information in their language.

Project Website

At the beginning of the project a website was developed. The goal of developing the website was to count with an important communication channel during the processing time of the GR3 project. All the documents created during the project are available under **www.grassgreenresource.eu**. Each report regarding the energetic utilization of grass residues can be downloaded there. In addition, all the events in the frame of the project are listed there and could be seen from the online users. The website is available in all the languages of the countries involved in the project. The online users can choose between Danish, Dutch, English, German, Italian and Portuguese. The project partners have also the benefit that their organisations' websites are linked with the project website as well as other relevant platform websites (in particular bio-energy platforms). It is a win-win-situation where all the participants have the opportunity to encourage their own networking.

Electronic newsletter

A four-monthly electronic newsletter was created and distributed six times between December 2013 and November 2015. The newsletter was mailed to the networks of the members of the project consortium, as well as to anyone who registered itself on the project website to become it or who filled up the project‘s leaflets. These brochures were distributed as part of the public relations work of the project partners in their different languages. The content of the newsletters concerned the progress of the project, related topics, the next events (for example informative meetings or workshops), updates on the project website and so one. The language of the six newsletters was English.

Participation in (inter)national conferences on bioenergy and waste management

The participation in international conferences was successfully achieved. During the running time of the project the different partners were part in related national and international events, particularly conferences on bio-energy, waste management or related themes to present the project and its results. Additionally the GR3 project was presented during these project events (conferences, seminars, workshops). The ways in which the project was addressed were presentation of results, poster presentation and other participations on different trade shows to get an active network.

Figure 19 GR 3 presentation on a conference

Figure 20 GR 3- Workshop Saarbrücken

Impact and Conclusions

In this document we have taken you through all the output that the GR3-project has created. By providing information from different angles (technology, legislation, economy, etc.) It should give you a good overview on the possibilities of valorisation of the grass-residues available in your region.

But what amount of grass-valorisation could we actually realize in the project?

During the project's lifetime, we have studied more than 20 cases that covered in total more than 70.000 tons of grass residues. Unfortunately, not all of the studied grass clippings will end up being digested, due to problems with the economies of the case (CBA) or legal-issues (waste vs. non-waste).

The total amount of grass that will be digested thanks to the GR3-project will be 25.000 ton each year (some of them still under negotiation by the time of writing). Now, what is the impact of this 25.000 ton that will be digested?

Primary energy saved	Renewable energy produced	Reduction of green house gases
67 t/y	**1.670 t/y**	**11 400 ton**
Due to reduced composting	Thanks to biogas production And wood-combustion (of wood that is not consumed by composting any more)	Thanks to avoided uncontrolled emissions (landfilling and composting) and savings of primary energy

Yet this is – for what we believe – not enough. There are more possibilities for grass digestion in the various regions, though we have to consider some important borders and obstacles that have great impact on the "willingness to digest" grass:

The economies are important

- The market of organic wastes
  In the region of Flanders it was noted that compared to 2 to 3 years ago, the interest from the digester side in grass digestion has decreased a lot. This is mainly due to the availability of a lot of (easy-digestible) organic waste on the market. This high avai-

lability is due to the low price of grain (for the farmers) and the failures of some important biogas installations. In case the "market would turn", and new biogas plants would be build, the organic waste on the market might become scarce again, and the interest from the digesters for grass as a feedstock will increase immediately.

- No gain when no costs

  A lot of the grass suppliers now just leave the grass on site (though it is sometimes illegal), which represents zero costs. Making a (profitable) business plan for delivering the grass to a digester is therefore very difficult (read impossible) as delivering it to the digester will always induce costs (transport, cleaning, etc.).

Legal issues with the status of grass

In almost all the different regions there is a limit on the ways the grass waste can be applied due to legal constraints. If considered "waste" it is not applicable in agricultural digesters in e.g. Germany and Italy. But it is only this latter type of digesters that could be interested in the digestion of the grass clippings. Sorting out these problems, and (especially) clearing up things should stimulate grass digestion in the future.

Policy support for new biogas-installations

In different regions (Germany, Italy and Belgium) there has been an important drawback in the policy support (read economic support) given to new biogas-installations. That makes that the interest in building new installations has dropped (to zero). On the other hand new biogas installations would be triggered more to digest grass – as they can include all necessary equipment from the very beginning of the project.
Knowing that the tools and information we provided will be available and usable also beyond the project's-timeframe, we are confident that one (or multiple) of the above mentioned constraints would change, there will be more grass digested. There is interest from organisation and people in the "field" (we have met with over 680 persons in our events!) though some basics have to change in order to have the grass digestion a "prosperous" biomass chain.

In the future, the importance of grass in agriculture will continue to increase. To this end, additional utilization patterns must be opened and grass valorization must be further optimized.

GR3
GRASS
TO GREEN GAS