EMPLOYMENT ANALYSIS

Date of publication : 24/7/2015 (V1.0)

Author(s) : Tom Depuydt (Pro Natura)

IEE project : IEE/12/046/SI2.645700 – GR3

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

Project website: http://www.grassgreenresource.eu/

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1 INTRODUCTION

The digestion of grass residues can have beneficial results for a number of issues. Not only does it allow for the energetic valorization of an untapped source of green energy. It can also actively replace the input of feed crops, such as corn, into an anaerobic digestion (AD) plant, resulting in an impact on the use of food crops in energy production. Furthermore, certain grass residues, such as grass clippings from roadside verges, constitute problematic biomass wastes. Proper disposal and processing of these waste streams is often not guaranteed, as they can be processed through the composting process, but are not really welcome due to their lack of structure (woody) material.

Another possible advantage of the digestion of grass residues lies in the creation of employment. Grass residues have to be harvested, collected and fed into suitable AD plants, which will demand a number of investments and adaptations of the valorization chain. These adaptations can be roughly divided in two categories: on one hand, a different approach is necessary to the mowing, collecting and pretreatment of the grass clippings. On the other hand, suitable AD plants have to be available to process this biomass waste stream, often necessitating investments. These adaptations and investments will result in the additional creation of employment opportunities, both in the construction of necessary equipment and installations, and in their daily operation. Certain steps in this valorization chain are ideally suited for low-skilled, disadvantaged laborers. Extra attention will therefore go to the concrete possibilities of employing this target group.

The intention of this report is to estimate the possible job creation which can potentially be achieved through the digestion of grass. As will become clear, this potential will be assessed through the use of both hands-on experience and literature data. As certain assumptions have to be made to be able to estimate employment, based on different possible scenarios, the result will not be a clear-cut number of jobs, but rather a range, depending on the implemented measures and pathways.

2 SCOPE AND METHODOLOGY

2.1 SCOPE

Anaerobic digestion of grass residues, which is the objective of the GR3 project, will be the main focus of this report for now. The adaptations in mowing works, collection and pretreatment of grass will be discussed and illustrated, with special attention to the inclusion of low-skilled workers. Also the investments in suitable AD plants will be covered, with attention to the current situation in the field of anaerobic digestion. In an updated report, different grass valorization scenarios, such as composting or the use of grass as cattle fodder, will be included, to enable comparison between different uses of grass.

Each of the partner regions or countries of the GR3 project (Flanders, Denmark, Germany, Italy, Portugal) has a grass stream which is more readily available than others. For Denmark, for example, this would be grass from natural grasslands. Different adaptations to the valorization chain will be necessary, depending on the source of these grass clippings. Therefore, the most important source for grass clippings will be determined per region, and the employment analysis will be based on this grass source. For Flanders, the source of the grass biomass which will be considered is roadside verge clippings, as these constitute the main volume of total grass residues available for digestion. In a further update to the report, the same analysis will be made for the other partner regions, based on their predominant grass source.

2.2 METHODOLOGY

Initially, estimates will be made on a local scale; a number of assumptions will be made to determine the scale of operations when grass residues have to be supplied to a single *typical* anaerobic digestion plant. This will allow to determine all the necessary inputs for a single plant to be able to successfully digest grass clippings. Furthermore, this will also allow to determine in detail the logistics involved, which will also impact the final employment potential. In an updated report, this will result in local differences between the different partner regions, as the typical digester will differ per region. Moreover, this local analysis will further enable comparison between the different scenarios of grass valorization.

This local analysis will involve the estimation of jobs created in the supply chain (mowing, collection, pretreatment). Data will be drawn from earlier experiments conducted by Pro Natura, or experiences from partners in the field. Job creation in AD plants will be calculated using literature values.

Once these estimates have been made on a local level, they can be extrapolated to the region as a whole. Based on the data available from the grass residue inventory, which was also conducted in the framework of the GR3 project, the total employment potential for a whole region can be determined. In first instance, this will concern Flanders, but this will be expanded to include all the participating regions later on.

3 LOCAL EMPLOYMENT POTENTIAL FOR GRASS VALORIZATION

Before an estimate can be made concerning the potential employment, a number of factors affecting the layout of the valorization chain have to be explored. After this, the supply chain can be defined and potential employment can be determined, both on the side of the supply chain, and on the side of the AD plant.

3.1 SITUATION IN FLANDERS

Based on the inventory data of the GR3 project (Pasmans, et al., 2014) the dominant source of grass residues in Flanders has been determined to be grass clippings from roadsides and waterways. Only these grass residues will be further considered in the estimation of potential employment. An annual 32 834,65 tons of dry matter (DM) are available. Calculated with 27% of DM content, this means that approximately 121 609,81 tons of fresh grass residues from roadside verges are available each year in Flanders. It has to be remarked however, that this is likely to be an underestimation, as large discrepancies between municipalities were noted during the inventory, likely to be the result of some municipalities disposing of their grass via other waste streams (thus these volumes do not end up registered separately by OVAM, the Flemish waste regulator).

Specifically for Flanders, the situation of the sector of AD plants is also of importance when considering the optimal route for biomass valorization. Although around 40 digestion plants are available, only two of these are of the dry digestion type (De Geest, et al., 2014). Although dry anaerobic digestion is seen as the Best Available Technology (BAT) for grass digestion, this application will in reality be limited for the region of Flanders, as there are simply not many digesters of that type available in the region. Furthermore, given the additional costs involved in dry digestion and the recent financial uncertainties in the sector of digestion (due to a changing policy framework), and given the Flemish reality, where co-digestion with manure is almost a standard practice for AD plants, additional investments in dry digestion plants should be considered unlikely in the near to mid-term future. It is therefore equally unlikely that dry digestion will play a significant role in the valorization of grass residues in this timeframe. Wet anaerobic digestion will therefore be considered as the main route for grass digestion in Flanders.

In order to establish the basis on which estimates for a local scenario can be developed, the typical size of a plant in Flanders has to be determined. Based on a review of the existing plants in Flanders (De Geest, et al., 2014), the capacity of such a plant was assumed to be 60 000 tons of biomass. Furthermore, it was assumed that around 10% of the biomass feed of said plant could be replaced with grass residues, resulting in the uptake of 6 000 tons of grass by one plant. This is well below the maximum capacity of 15% to 20% grass uptake that such a plant could technologically handle, but a safety margin was taken into account, given the easy mixing of grass in the digestion reactor, and that the biogas potential of grass residues is somewhat lower than that of other biomass feedstocks such as corn.

3.2 SUPPLY CHAIN

3.2.1 CHALLENGES

As noted before, wet anaerobic digestion is not considered as the BAT for grass digestion. The impact of this is that certain extra measures are necessary before the digestion of grass in wet AD plants will be feasible. Most of these measures concern adaptations to the supply chain, in order to ensure the delivery of an optimal resource to the AD plant. Once these adaptations have been implemented, further processing through wet digestion should be possible, requiring minimal adaptations to the plant itself.

Three main issues exist which, if not amended, prohibit the use of roadside grass clippings in a wet digestion plant:

1) *Presence of soil and sand particles*

Traditional mowing equipment – of the flail-type – will result in the uptake of significant amounts of soil and sand particles with the grass clippings. These particles have a particularly abrasive effect on the pumping and piping installations of wet anaerobic digesters. Furthermore, they will settle in the reactor of the digestion plant, creating dead volume and resulting in a loss of generated biogas.

Figure 1: Ecological mower (Herder ECM 160) (Cardoen, 2013).

However, the uptake of these particles can be largely avoided if the mowing equipment is adapted. Testing of a so-called ‘ecological mower’ by Pro Natura pointed out that the uptake of soil particles can be largely prevented when using this type of circular mower (Figure 1). A comparison between the ecological mower and a traditional flail mower shows that whereas the former would take up at most 0,4% of soil particles (per ton of fresh matter), this would increase to 2% with the latter, or even 16% when used sub optimally (Cardoen, 2013). This can be largely explained by the fact that the ecological mower applies less suction to the soil to remove the grass clippings. This mowing combine was originally developed to leave insects and seeds in place. As a side effect, through the reduction in suction, it also takes up less soil, and furthermore uses less fuel.

2) Presence of litter

Inherent to roadside verge clippings is the presence of litter as a fraction of the waste. Sadly, this is a recurring problem, which has to be taken into account when processing the grass residues. Just like soil particles, this litter will result in damage to pumping and piping installations, and dead volume inside the digestion reactor.

Figure 2: Litter removal from grass residues.

This problem can be addressed by the social economy, employing low-skilled labor. Once the grass residues (which contain the litter) have been collected and transported to a suitable location (preferably the site of the digestion plant), they can be processed by social economy workers to remove the litter. Again, Pro Natura took part in an experiment in which the grass clippings of several municipalities were collected, processed and digested (Balis, 2011). In the course of this experiment, the feasibility of litter removal from grass residues was demonstrated.

3) Size of the grass clippings

As the grass from roadside verges or waterways is only mown once or twice per year, the resulting grass stalks can be of significant size. This will result in clogging and damage to the pumping installation of the digestion plant.

In this case, the use of a shredder can provide a solution; the grass stalks can be cut to an optimal length of 1-2 cm, thus preventing the clogging of pumps and pipes.

3.2.2 LAYOUT OF SUPPLY CHAIN

Taking into account the previous challenges, the supply chain needs to be adapted to reflect all the necessary changes. Once this supply chain has been established, the accompanying employment potential can be estimated. It should be noted that an adapted supply chain will likely result in higher total costs to enable grass digestion. To offset this, extra actions will also generate additional employment.

In general, the following diagram can be a suitable guide through the supply chain:

Figure 3: The supply chain in the valorization of grass residues.

- *Mowing:* As noted before, we will consider mowing with an ecological mower of the circular type. Based on field experience, this will not result in different mowing speeds or otherwise impact the logistic chain. Therefore, the impact on additional employment is assumed to be negligible. However, in Flanders the practice of obstacle mowing is important in roadside verges, for reasons of safety; around traffic signs, lighting posts and other objects in the roadsides, low-skilled laborers can be employed to mow grass.
- *Collection:* Just as with the traditional flail mower, the ecological mower is capable of collecting the grass residues right after mowing. These clippings are sucked into a trailer. In an ideal scenario, the mowing combine can keep working, and whenever its trailer is full, this can be detached.
- *Transport:* Whenever a trailer is detached, this can be transported to a central biomass hub, either on- or offsite of the digestion plant. The transport to this biomass hub shouldn't be done by the mowing combine itself, but rather by dedicated lorries. This will allow timesaving for the mowing combine, and faster transport and processing of the grass wastes.
- *Pretreatment:* Once arrived at the biomass hub, the grass needs to be cleared of litter and shredded. Again, social economy labor is ideally suited for these tasks. The grass can be put on a conveyor belt to allow easy litter removal, after which it is fed directly to the shredder. After the correct processing of the biomass, it can either be fed to digestion plant directly, or ensilaged for further use.
- *Ensilage:* To prevent the loss of biogas, every precaution must be taken to properly ensilage the grass clippings. If done well, the resulting loss in biogas potential of the biomass should be minimal, allowing the digestion of clippings for more than a year after storage.

3.3 ANAEROBIC DIGESTION PLANT

Based on field trials, it is assumed that no extra adaptations are necessary to existing wet AD plants, but for one exception. When digesting grass, these plants should invest in floating layer breakers, as these will form inside the digestion reactor. However, as most Flemish digestion plants already dispose of such equipment, it is not taken into further account.

Extra employment due to grass digestion in existing biogas plants will therefore be limited. Nonetheless, we can estimate the employment which is 'dependent' on the grass digestion, if a new or existing plant were to take up grass. Again, a typical plant with a feed rate of 60 000 tons per year will be taken into account, with an uptake of 6 000 tons of grass residues.

3.4 LOCAL EMPLOYMENT POTENTIAL

3.4.1 SUPPLY CHAIN

Table 1 provides an overview for the working hours generated per ton of fresh grass clippings. To clarify, the reasoning behind each step in the supply chain is provided below:

- *Mowing:* Based on field experience from partners, a working speed of 2,5 km/h during mowing is assumed, taking into account transport between verges, delays... Given the standard mowing width of 1,60 m of the cutter bar, this results in a mown surface of 0,4 hectares per hour. We use the same assumptions as in the grass residue inventory, of 4 tons of dry matter grass residue per hectare of roadside per year, and a dry matter content of 27% (Pasmans, et al., 2014). However, as roadside verges are mown twice per year on average (June and September), a yield of 2 tons of dry matter per hectare per mowing is expected. This results in 2,97 tons of fresh grass clippings per hour. This means it takes around 0,34 hours to mow one ton of grass.
- *Collection:* The collection of the grass happens automatically during the mowing works. It will therefore not provide any additional work. After the trailer is filled up, it should be detached and replaced with an empty one, to allow optimal logistics in the supply chain.
- *Transport:* To have an idea about the mean distance for which the grass has to be transported, a simple model can be used. Given the total tonnage of roadside grass residues (121 609,81 tons, see before) and the total area of Flanders (13 522 km^2), one needs an area of 667,16 km^2 to collect the necessary 6000 tons of grass for one digestion plant. This area corresponds with a circle with a radius of 14,57 km. If we assume the plant to be in the middle of said circle, the mean distance of transport equals 2/3 of the radius, or 9,71 km. (Given that the mean distance from an arbitrary point in a circle to the middle is equal to 2/3 of the radius of said circle.) Given the rather small distances involved, such a transport will mostly bypass highways, instead sticking to local roads. Therefore a detour factor of 1,4 is assumed, extending the trip to 13,59 km. Also allowing for picking up and dropping off the trailers, a mean speed of 30 km/h is taken into account.

  Furthermore, we assume that one transport can move 30 m^3 of grass residues. Given a density of around 200 kg/m^3 for grass clippings, this means 6 tons of grass can be moved per transport. Lastly, the empty ride towards the collection point has to be taken into account. Combined with the previous, this means it will take 0,91 hours for one transport (both ways). This means 0,15 hours per ton of grass.
- *Pretreatment*: As explained before, this step entails litter removal and shredding of the grass stalks. Based on data from an earlier pilot project, it is assumed litter can be removed from grass at a rate of 1,55 tons of grass per hour, by 1 person (Balis, 2011). The grass can be fed to the shredding machinery simultaneously. This results in 0,65 hours of work per ton of grass clippings.
- *Ensilaging*: The final step is assumed to result in no additional working hours. The reasoning behind this being that ensilaging constitutes a marginal step in the supply chain when it comes to time consumption.

Table 1: Working hours per ton of fresh grass clippings, for each of the steps in the supply chain.

Action	*Working hours (h/ton of fresh grass clippings)*	*Working hours total (h/6000 tons grass)*	*Jobs generated (per 6000 tons grass)*
Mowing	0,34	2040	1,30
Collection	0	0	0
Transport	0,15	900	0,57
Pretreatment	0,65	3900	2,50
Ensilage	0	0	0
Total	*1,14*	*6840*	*4,37*

For each of these steps, Table 1 also includes the equivalent working hours to supply 6000 tons of grass clippings. To translate these annual working hours to actual jobs, for Flanders the average annual hours actually worked per worker for Belgium in 2013 were taken into account, 1576 hours (OECD.Stat, 2015). As can be seen in Table 1, work in the supply chain amounts to 4,37 jobs to supply one typical Flemish plant with grass clippings.

There are two important remarks however. First, it should be noted that in all likelihood only the pretreatment provides any *additional* work compared to the present situation. This is because Flemish law already stipulates that roadside verges should be mown, and the grass waste removed (transported) and disposed of in a certified processing installation. And secondly, it could be remarked that additional work is created through the construction of necessary machinery for the supply chain. However, for the same reason this is not included here; most of the machinery (mowing combine, transport…) is already necessary under the present conditions. Therefore adapted machinery is unlikely to result in much additional work.

3.4.2 ANAEROBIC DIGESTION PLANT

As noted before, taking up grass residues is unlikely to result in any additional work for existing digestion plants. The grass residues will be used to replace another feedstock, while only minimal (if any) adaptations are necessary to the machinery of the plant. Nonetheless, we can determine how much work in existing plants will be 'dependent' on the grass residues or, in case the necessary investments are made, how much work would be created in new plants.

Again, a typical plant of 60 000 tons is considered, with the possibility of digesting 6000 tons of grass. However, the number of jobs which will result from the uptake of grass is not simply 10% of the total workforce of the biogas plant. The output of the plant (which is energy) determines its profitability. This means that the work which is created in such a plant also depends on the energy output of its feedstock. Therefore, the proportion of the workforce which depends on grass digestion, should also reflect the biogas yield of grass clippings versus the usual feedstock.

For Flanders, the total uptake of biomass for digestion was 1 630 000 tons in 2013. This resulted in 602 GWh of power generated in that same year (De Geest, et al., 2014). In other words, one ton of biomass generated on average 369,33 kWh of power. For the digestion of grass residues on the other hand, we assume that 1 ton of fresh or ensiled material generates 100 m^3 of biogas. Under the assumption that 60% of that biogas is methane, and 1 m^3 of methane generates around 10 kWh of energy, 600 kWh of energy could be generated from 1 ton of grass clippings. To determine the power output, a rule-of-thumb is used; 1/3 of the energy output can be converted to power. This means that 1 ton of grass generates 200 kWh of power.

Taking the above into account, we can determine how much of the energy output, and therefore workforce, depends on grass digestion. In a 60 000 ton plant, 10% of the feedstock generates 200 kWh of power, while 90% creates 369,33 kWh of power per ton. This results in:

Table 2: Percentage of power output to be generated by the digestion of grass clippings in a Flemish plant.

Total power output:	21 143 820 kWh
Of which average biomass:	19 943 820 kWh
Of which grass:	1 200 000 kWh
% output by grass digestion:	5,68 %

Therefore, 5,68% of the workforce in a biogas plant which takes up grass residues, can be considered to be dependent on grass digestion.

To evaluate the real job potential through grass digestion in a biogas plant, literature data is used. It is estimated that up to 560 people can be employed per TWh per year of generated electricity, while the equivalent of 140 people will be employed in the construction phase of this installed capacity (Olesen, et al., 2006) (Lovrencec, 2010). The latter means 2000 job years are generated during the construction of a plant producing 1 TWh of electricity and with an expected lifetime of 14 years.

Extrapolated to the plant described in Table 2, with an output of around 21,14 GWh, this results in:

Table 3: Jobs dependent on grass digestion in a Flemish plant.

Biogas plant	Jobs generated for whole plant	Jobs dependent on grass digestion
Construction	2,96	0,17
Operation & Maintenance	8,88	0,50
Total	*11,84*	*0,67*

All in all, 11,84 jobs are created in the construction, operation and maintenance of the plant. Of this, 5,68 % is dependent on grass digestion, or 0,67 jobs. These stem mainly from operating and maintaining the plant (0,50 jobs), rather than construction of the plant (0,17 jobs).

3.4.3 OVERVIEW OF LOCAL EMPLOYMENT

Given the initial assumptions and constraints, the previous results have been summarized in Table 4. The most important assumption is that we're looking at a typical Flemish agricultural digester, with a capacity of 60 000 tons of biomass. Given the assumption that 10% of the feedstock, or 6000 tons, could be replaced by grass clippings, this results in a total employment of 5,04 Full Time Equivalents (FTEs).

Table 4: Summary of local employment potential for grass digestion by Flemish plant.

Step in grass valorization chain	Jobs generated
Supply chain	4,37
Mowing	1,30
Transport	0,57
Pretreatment	2,50
Biogas plant	0,67
Construction	0,17
Operation & Maintenance	0,50
Total	*5,04*

The resulting work in mowing and transport is rather limited (1,87 FTEs). This is mostly due to the fact that logistics have to be optimized. At the moment grass clippings are either disposed of at a composting plant by the mowing combine itself (resulting in slow transport) or dumped in temporary 'waiting stacks'. However, to prevent loss of biogas potential, the clippings need to be processed (digested or ensiled) quickly in case of digestion. Therefore, inefficiencies such as the mowing combine itself providing transport, will be less feasible. However, note should be taken that extra costs will be incurred due to more complex logistics.

The potential for social economy is found in the pretreatment of grass residues (2,5 FTEs). As grass clippings become available only during a certain peak period (June-September), this allows for seasonal work by a larger 'biomass team' of around 7 to 8 laborers at one biomass hub or digestion plant. These can also be put to work in attending the smooth operation of the biomass hub and ensilaging.

If an existing or new AD plant decides to digest grass, this will result in 5,68% of its employment being dependent on the power output of grass digestion. As such, another 0,67 FTE are created by taking up grass digestion.

4 TOTAL EMPLOYMENT POTENTIAL FOR GRASS VALORIZATION

Based on the previous evaluation, a total employment potential can now be estimated for the whole region of Flanders. As noted before, approximately 121 609,81 tons of grass clippings from roadside verges are available. Under the assumption that all these residues are digested, this results in the following job creation:

Table 5: Total employment potential if all roadside grass from Flanders were to be digested.

Step in grass valorization chain	Jobs generated
Supply chain	88,57
Mowing	26,35
Transport	11,55
Pretreatment	50,67
Biogas plant	13,58
Construction	3,45
Operation & Maintenance	10,13
Total	*102,15*

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 as should be. Of course, this also results in an underestimation of the employment potential which 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.

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